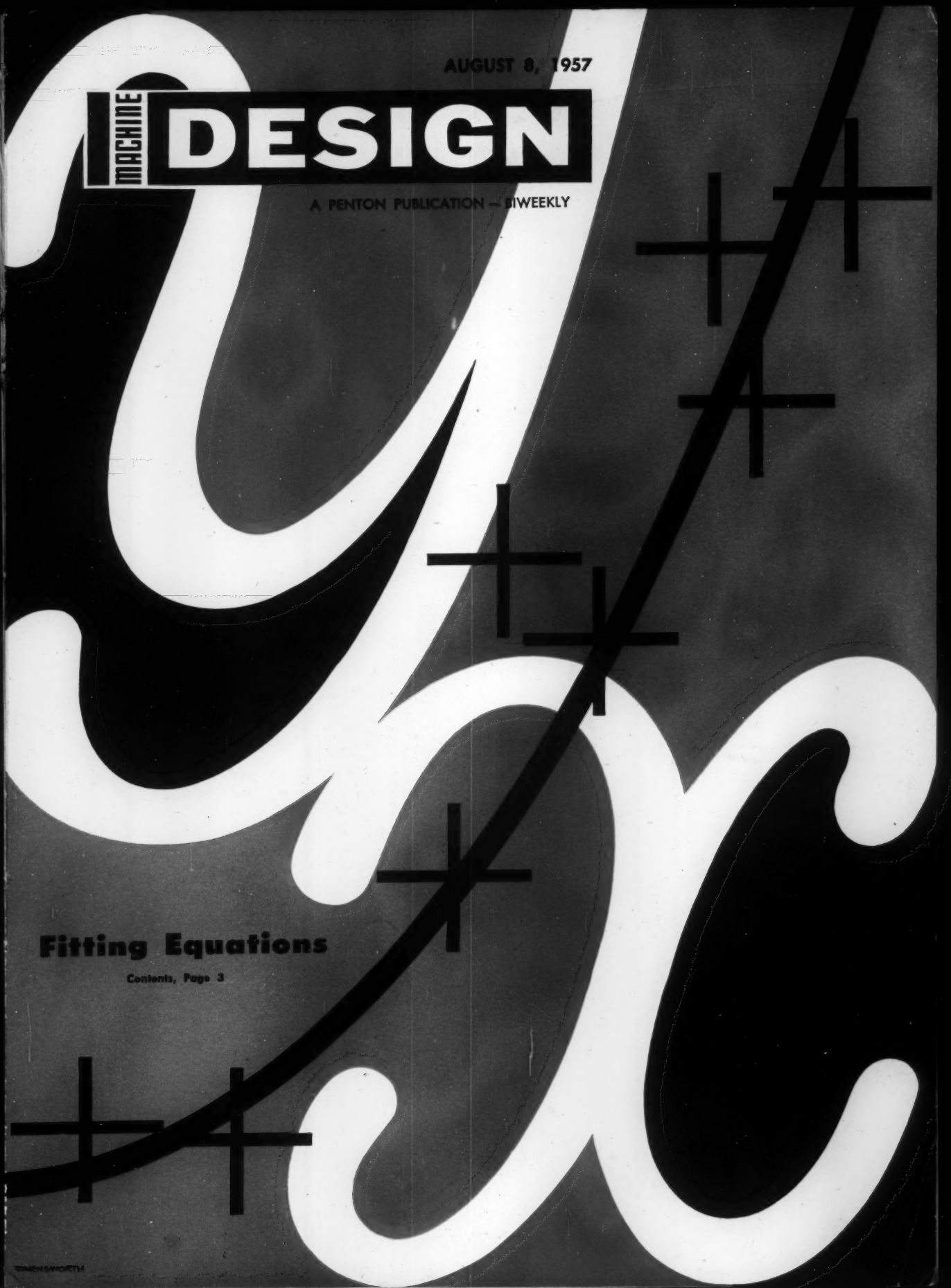
AUGUST 8, 1957

MACHINE DESIGN

A PENTON PUBLICATION — BIWEEKLY



Fitting Equations

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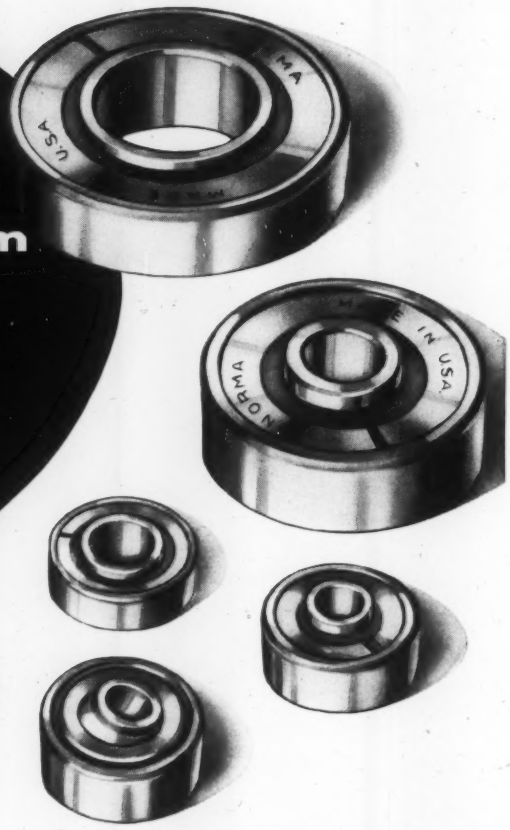
Precision

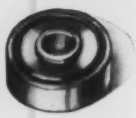
Aircraft Control System

Bearings

by

Norma-Hoffmann



Combine  *Free Turning with High Load Capacity*

Norma-Hoffmann precision ball bearings for aircraft control systems are engineered to furnish maximum load-carrying capacity and assure control system rigidity, sensitivity and instant response.

They are available in two basic designs:

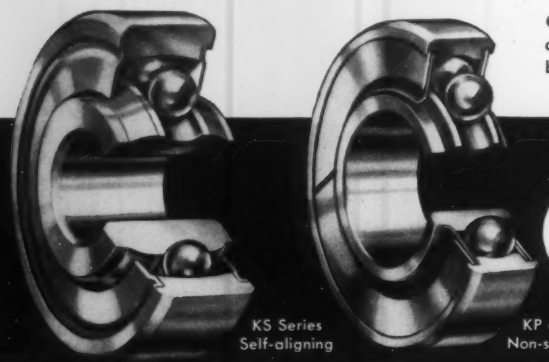
"KS" Series — self-aligning up to 10° in either direction — with permanently attached stainless steel shields.

"KP" and "KP-A" Series — non-self-aligning — with removable composition seals.

All Norma-Hoffmann Aircraft Control Bearings are:

1. Made with a full row of balls and specially close raceway curvatures — to carry maximum load.
2. Designed with inner rings extended at each side to simplify mounting.
3. Prepacked with metered quantity of MIL-G-3278 specification grease.
4. Cadmium plated on all exposed surfaces.
5. Qualified under Air Force-Navy aeronautical standards.

Get positive protection against bearing failure in your aircraft control systems — specify and use Norma-Hoffmann precision bearings. Write for complete specifications.



KS Series
Self-aligning

KP and KP-A
Non-self-aligning

precision ball, roller & thrust bearings

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BEARINGS CORPORATION • STAMFORD, CONN.

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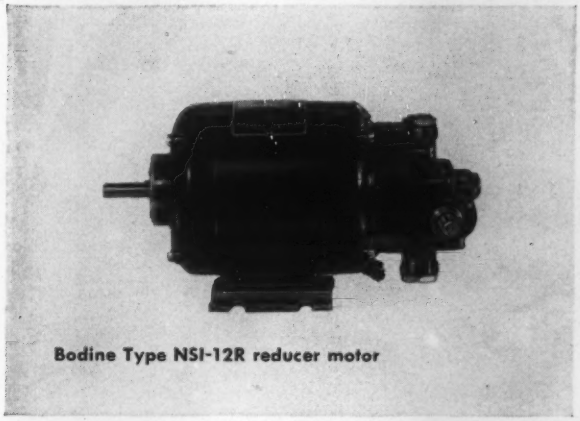
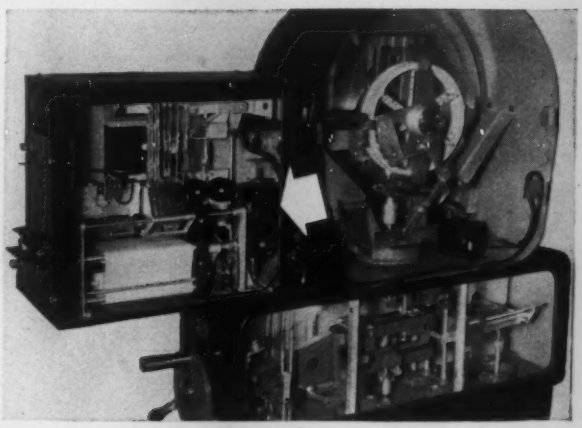
Fairbanks-Morse Printomatics use BODINE MOTORS because . . . "THEY ARE COMPACT, WITHSTAND YEARS OF HARD USAGE"

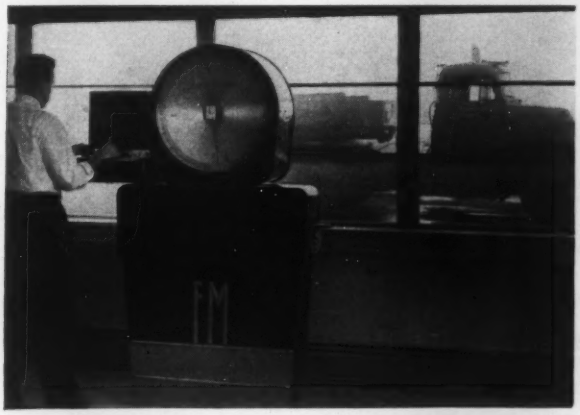


Bodine Type NSI-12R reducer motor

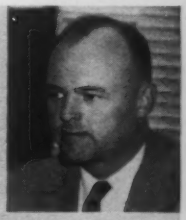
This Bodine motor is used in the Fairbanks-Morse Printomatic which prints a record of each weighing. The outstanding service record set by Bodine motors over the past twenty years—under the adverse operating conditions at truck weighing stations, and the high-speed weighings in industry—is the reason Bodine motors are "standard" on all Fairbanks-Morse Printomatics.



Here's an inside view of the Fairbanks-Morse Printomatic showing how the compact Bodine motor is positioned. This 1/70 HP, 1725 rpm reducer motor with a gear ratio of 72:1 actuates the selector fingers, which set type segments in the correct sequence, and then prints the indicated weight. This Bodine motor is often called upon to print weighings at rates up to 300 and 400 an hour.



Equipped with the Printomatic, this modern Fairbanks-Morse Scale combines precision performance with dependable and convenient recording. Printomatic units can be furnished with press keys to identify source of material, dates, quantities, payment, and other desired information at the time of weighing.



Mr. H. M. Goodchild, chief engineer, Fairbanks, Morse & Co., St. Johnsbury Works, gives the reasons they have standardized on Bodine Motors for all of their Printomatics . . .

"For over twenty years, Bodine Motors have been standard on all Fairbanks-Morse Printomatics. This precision equipment calls for a motor of small size that will stand up during years of hard usage under adverse conditions. Often operated thousands of times a day, month after month, Bodine motors continue to give satisfaction with little or no service."

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Circle 404 on page 19

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August 8, 1957 Volume 29—No. 16

THE PROFESSIONAL JOURNAL FOR ENGINEERS AND DESIGNERS

MACHINE DESIGN

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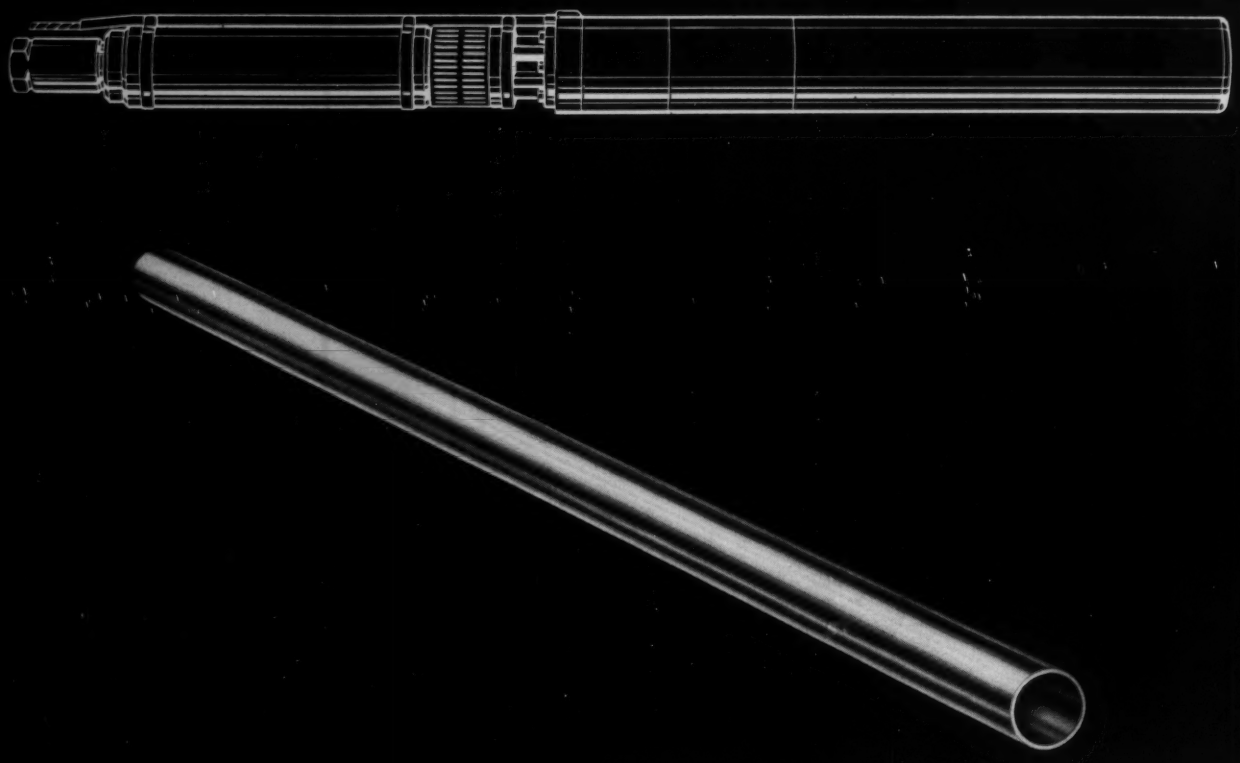

B&W ERW Mechanical Tubing Saves Time, Cuts Pump Production Costs 50%!

One manufacturer of submergible pumps had a bottleneck in its production line. The company had been using seamless tubing for their motor housings and pump housings—the design of the units called for precision tubing with close I.D. tolerances.

The company turned to B&W Electric-Resistance-Welded Mechanical Tubing.

After two years of using this close tolerance tubing, company engineers estimate they have been able to reduce their production costs on the components as much as 50%. What's more, the production of these parts has become the least troublesome in the manufacturing process!

Here's another example pointing out where B&W ERW Tubing is being used by industry to produce better products at lower cost. B&W Mechanical Tubing is available in a wide range of sizes, shapes, analyses, and finishes.

Get all the facts on savings from Mr. Tubes, your link to B&W. Call your local B&W tubing distributor. Write for Bulletin TB-419. The Babcock & Wilcox Company, Tubular Products Division, Beaver Falls, Pa.

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Seamless and welded tubular products, seamless welding fittings and forged steel flanges — in carbon, alloy and stainless steels

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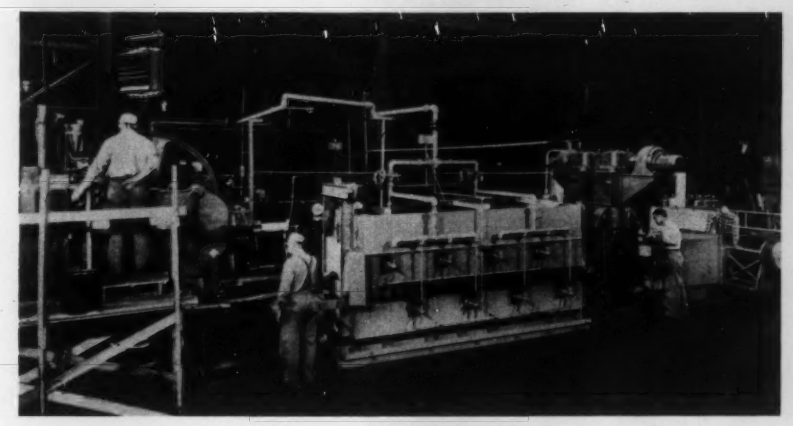
Engineering News Roundup



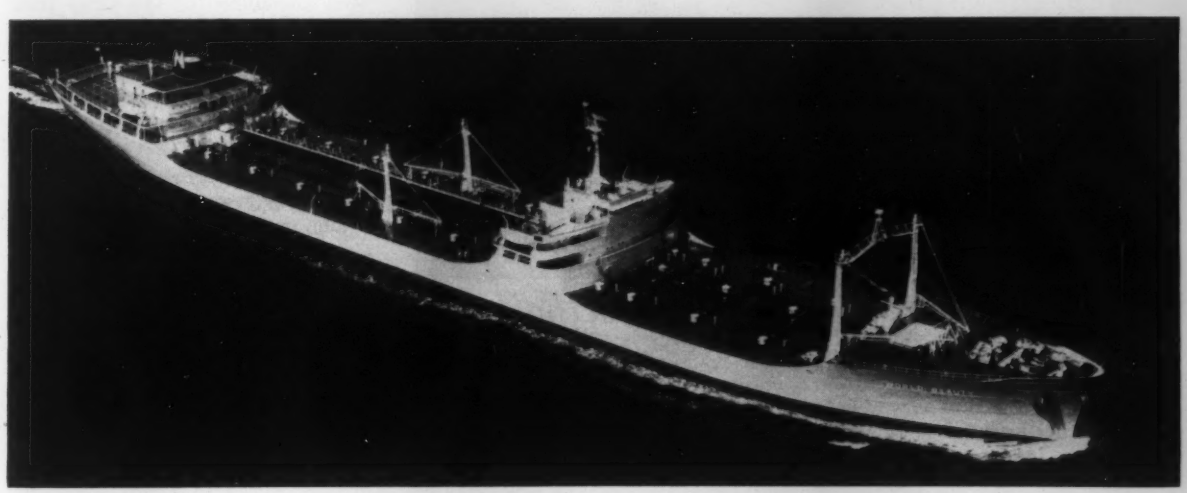
DIRECTLY FROM METAL POWDER, this new sintering equipment forms metal strip and tubing without first melting the powder into cakes or ingots. Metal powder feeds from the hopper at top left through compacting rolls, then passes through a sintering furnace and hot mill rolls. Finished strip compares favorably with fine strip rolled by conventional technique. Savings are claimed up to 80 per cent of conventional rolling costs. Process applies to copper, nickel, titanium, other metals. Chemetals Corp. holds the process license rights. Prototype machine shown here in first released photo was built by E. W. Bliss Co. and installed at the Bliss plant, Salem, Ohio.

ASME's Ryan Says ME's Must Up-Date Scope of Their Field

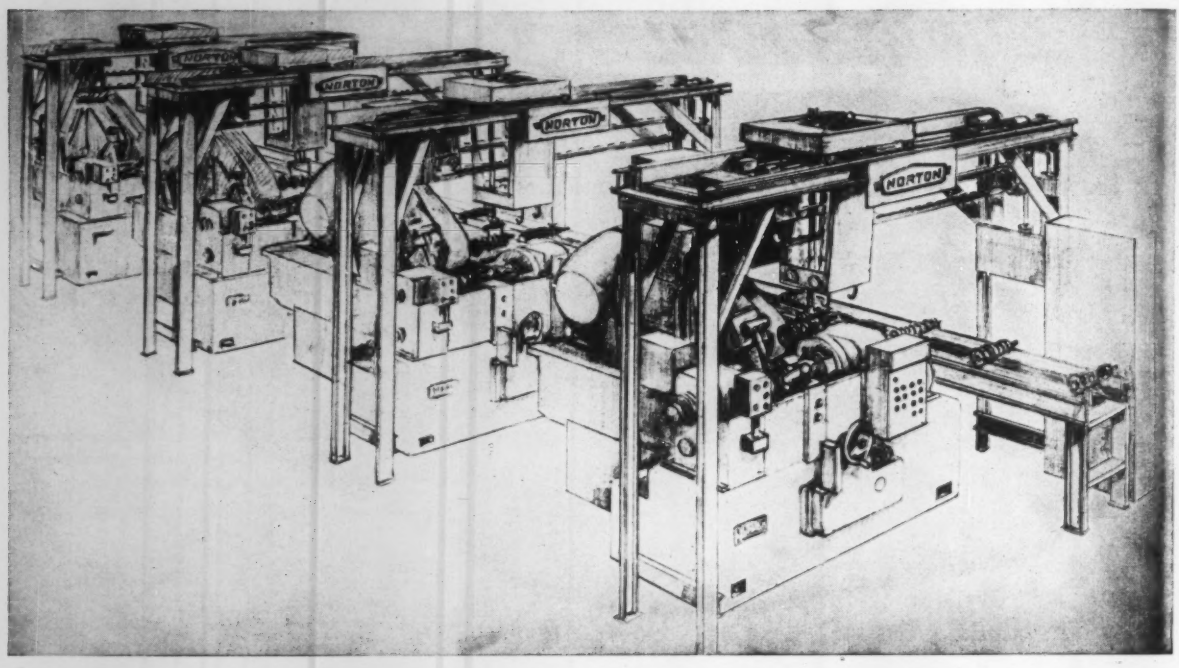
Survey of License Laws Could Spur Profession's Redefinition

SAN FRANCISCO, CALIF.—Mechanical engineers would be hard put if asked to write an up-to-date definition of their profession, according to Dr. William F. Ryan, president of ASME. But this is exactly what they must do—soon—in order to organize the profession more effectively and thereby maintain its unity, solidarity and group consciousness.

Dr. Ryan said that with the rapid expansion and diversification of engineering work brought on by technological advances, the profession is "bursting its seams and will fly asunder unless we take stock of what we are and what we are doing." He contended



LARGEST CARGO SHIP from U.S. yards is the tanker *World Beauty,* rated 46,000 deadweight tons, recently completed at Quincy, Mass., by Bethlehem Steel Co. and added to the Niarchos petroleum carrier fleet. *World Beauty* can carry 395,500 bbl or 16,500,000 gal of crude oil and can pump this cargo at one million gal per hr. The ship is too big for the Suez Canal. Its overall length is 736 ft; beam, 102 ft; draft, 50 ft. A 15,000-hp steam turbine and single propeller drive *World Beauty* at 17-knot service speed. Its 55-man crew have air-conditioned quarters and a swimming pool. *World Beauty* will soon lose its size superlative, however, for Bethlehem is scheduled in the next two years to deliver two larger ships of the same type to the same customer.



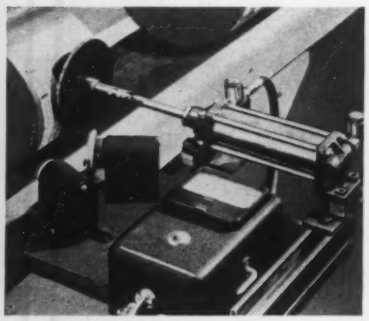
AUTOMATIC CRANKPIN GRINDER, developed by the Norton Co., consists of several identical units each of which grinds one pin on processed shafts. This arrangement permits machine units to be removed and replaced individually, as for servicing, without slack in production. Conveyors connect the machines; carry shafts between stations. Each station has its own crane which handles two shafts simultaneously to minimize machine idle time. On four-pin, automotive-type crankshafts, machine can finish-grind 240 pins per hour.

that engineers are frequently unable to distinguish their work from that of scientists or technicians.

He said that preliminary moves are already under way to conduct a survey of engineering comparable to the famous Flexner Report on medicine. Published in 1910, the Flexner Report is generally credited with eliminating medical quacks in this country and raising the standards of medical education.

The study of engineers is currently contemplated by Engineers' Joint Council and Engineers' Council for Professional Development. General purpose of the survey is to enhance the usefulness of engineering to industry, the nation, and mankind. Point of approach is the study of professional registration laws. Currently, they vary widely from state to state.

Despite the handicaps under which the profession labors, Dr. Ryan claims that American engineering education is the best in the world. A survey would not reveal any such scandalous conditions in engineering as existed in medicine prior to the Flexner Report.



DIFFERENCE IN COLOR of label and package is detected by an electric eye to activate air cylinder push-off arm on this materials handling device made by Sage Equipment Co. Package will continue past if label is turned away from light beam.

Contest for casting design has been announced by the Gray Iron Founders' Society for a design or redesign of a product to use gray or ductile irons. Entries will be judged on (1) how the design did or could increase product efficiency, (2) cost savings, (3) potential commercial importance of the entry to the gray iron industry as a whole, or (4) ingenuity of the design. A suggestion for a new use for gray iron also constitutes a valid contest entry.

Top prize of $500, second prize of $100 and third through seventh awards of $50 each will be given.

Front Cover

Using the fitting of a curve to experimental data points as his main theme, George Farnsworth has created a free-flowing pattern of color. The method of least squares for fitting equations is covered in Charles Tiplitz' article on Page 108.

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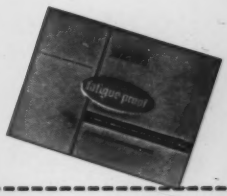

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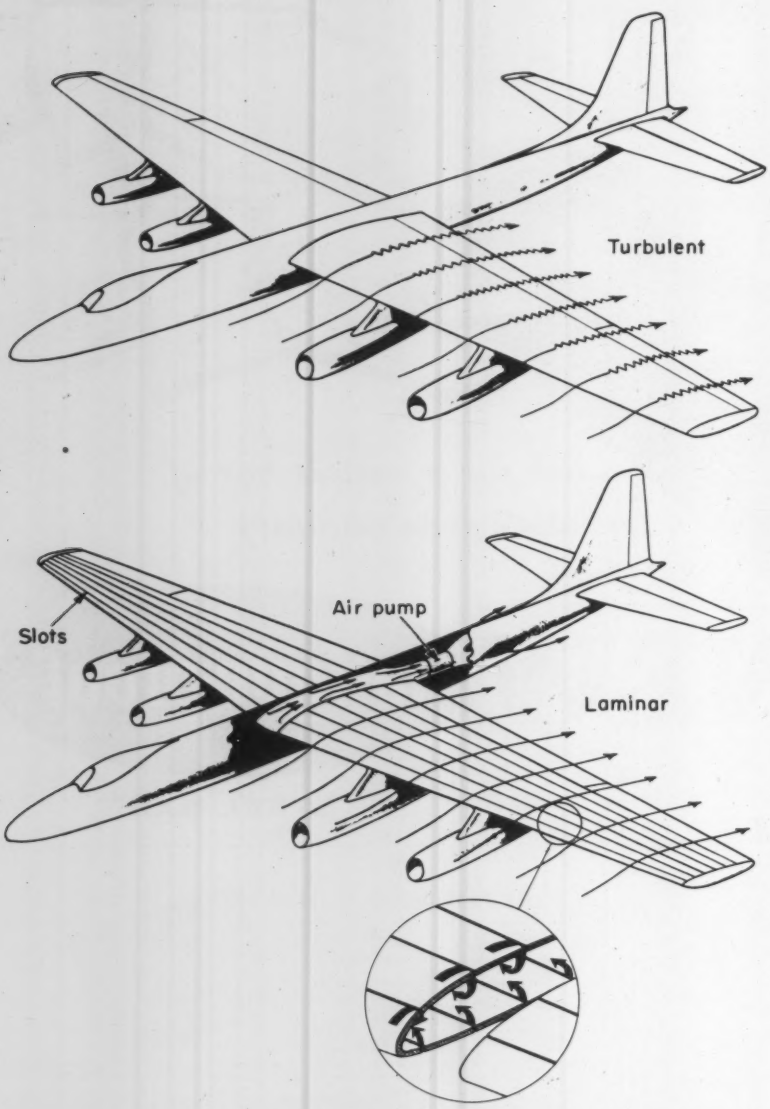


GREATLY INCREASED RANGE AND PAYLOAD may be possible through new application of this design concept. Northrop Aircraft Inc. reports unusual success after seven-year testing program on "low-drag boundary layer control." Aircraft performance is improved (below) through elimination of drag caused by turbulent air passing over wing and tail surfaces. Suction pump driven from main engine draws turbulent air into wing slots, exhausts it astern adding to jet thrust. This partially compensates for added weight of system. Extensive tests, using F-94 jet fighter have resulted in drag reduction of approximately 85 per cent.

all other entrants will receive a set of six GIFS technical manuals. Entries will be judged by a committee of impartial foundrymen under the chairmanship of Colin Carmichael, editor of MACHINE DESIGN.

Official entry blanks and information on the contest can be obtained from the Gray Iron Founders' Society, 930 National City-E. Sixth Bldg., Cleveland 14, O. The contest closes August 20, 1957.

Topics

More engineering students were enrolled in colleges during the last academic year than any other year since 1948. The ASEE reports that students in engineering accounted for 12.5 per cent of the total number of men attending colleges, 0.4 per cent over the previous year and following a general upward trend.

• • •

Transistor use will increase almost fivefold in the next two years, according to a survey made for Philco. By 1959, output is expected to reach 125 million units; this year about 26 million transistors will be produced.

• • •

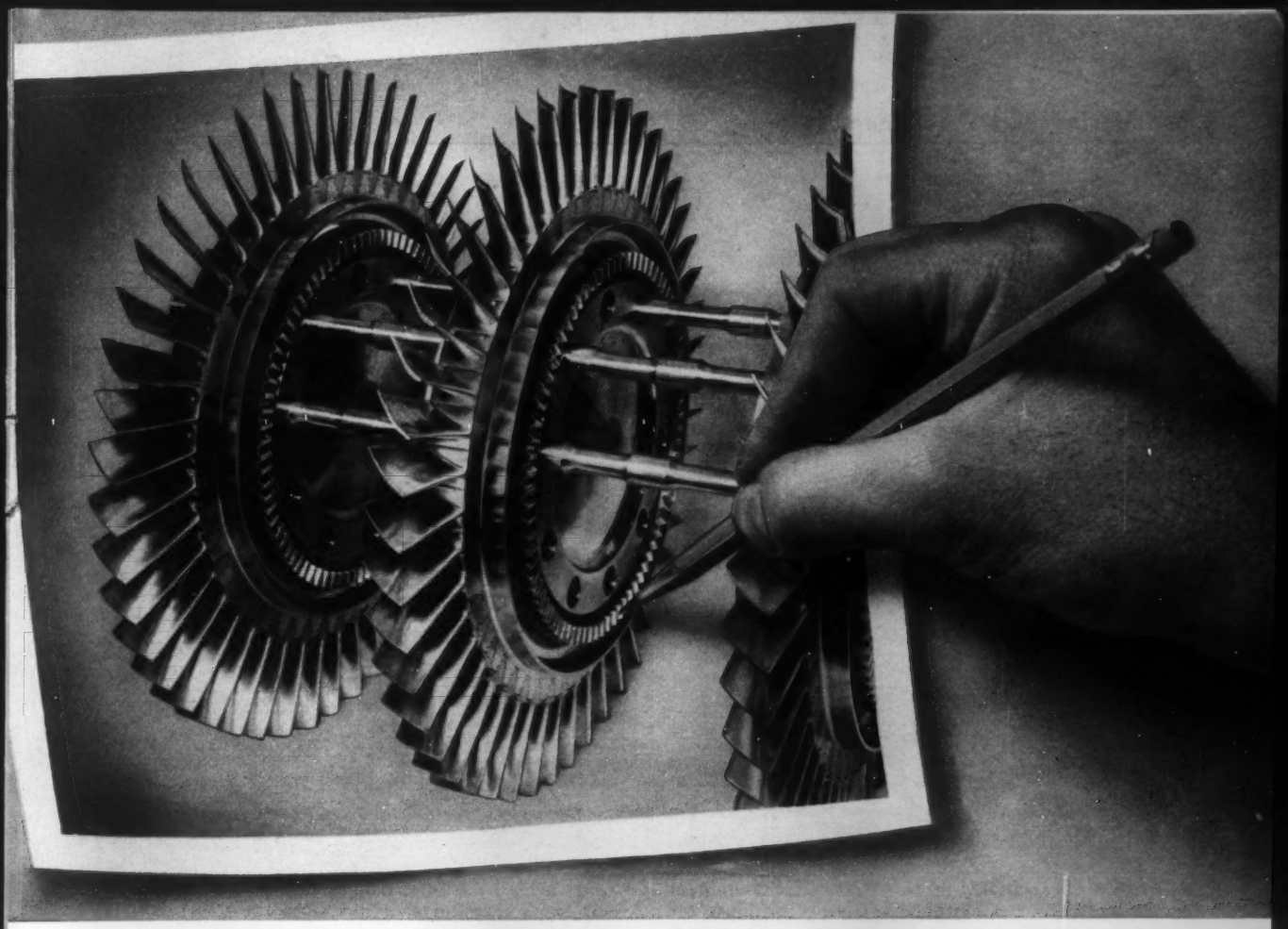
Taking the pulse of a whale, obviously not the most accessible or co-operative of subjects, was accomplished recently with the aid of wire cable and electronics. In the interest of medical science and electronic research, whales were struck with harpoons attached to stainless steel cable. Electronic pick-ups, floating short wave transmitters, and shore and ship-based receivers made possible the recording of heartbeat impulses onto cardiograph tape for later study.

• • •

Deep conversations can be held by skin divers equipped with Aquavoxes, small, 7-lb combination transmitting and receiving sets, said to be the first to carry voices a considerable distance through water. In transmitting, the device converts speech into electrical energy, then into a compressional wave form that will carry through the water. The receiving Aquavox reconverts the wave into electrical form, then into audible speech. Range is about 2000 yards.

• • •

Human-type brain outwitted a mechanical one in a recent checker-playing contest. The mechanical brain belongs to an IBM 704 computer installed at Massachusetts Institute of Technology; the human brain, to Mr. Saul Weslow. It seems only fair to mention that the computer is fairly new at this sort of thing and had previously beaten several people, while Mr. Weslow has played checkers for 35 years and is a member of the American international team.



Can CURVIC® Couplings lower the cost of your product?

They have done so for scores of manufacturers, by reducing machining time, by saving time in assembly and by permitting more compact design.

CURVIC Couplings are extremely accurate toothed connections which combine the functions of driving, centering and alignment.

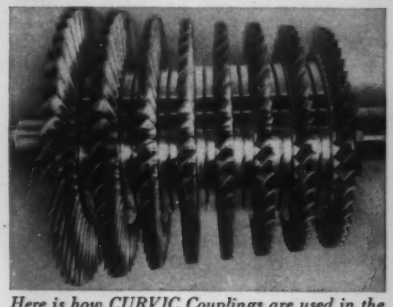
With CURVIC Couplings, complex machine parts can be made in several smaller units and then bolted or otherwise fastened together. Experience has proved that fabrication of many large parts in smaller units has reduced the time spent in machining, simplified final assembly, and reduced over-all manufacturing costs.

And there is no sacrifice of precision —in fact, CURVIC Couplings are so accurate that tolerances in the finished assembly can be held closer than when the part is made by any other means.

CURVIC Couplings are used in such applications as heavy-duty gas turbine rotors like the one shown above, jet engines, crankshafts and camshafts.

In addition to fixed or permanent connections, CURVIC Couplings can be produced in semiuniversal, and in releasing clutch types.

All types of CURVIC Couplings are produced rapidly, economically, and with high precision, on Gleason Cutting and Grinding Machines. If you would like to know more about CURVIC Coupling design or manufacture, the Gleason Works will be glad to consult with you, and to make recommendations about your specific applications. Write for our booklet.



Here is how CURVIC Couplings are used in the production of an 8-stage heavy-duty gas turbine rotor, holding it in perfect alignment under the severe stresses encountered at high speed.

GLEASON WORKS

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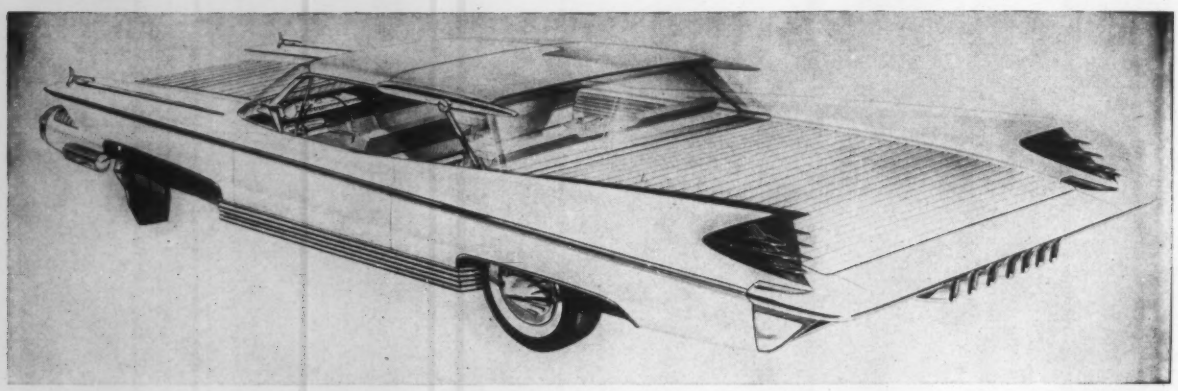
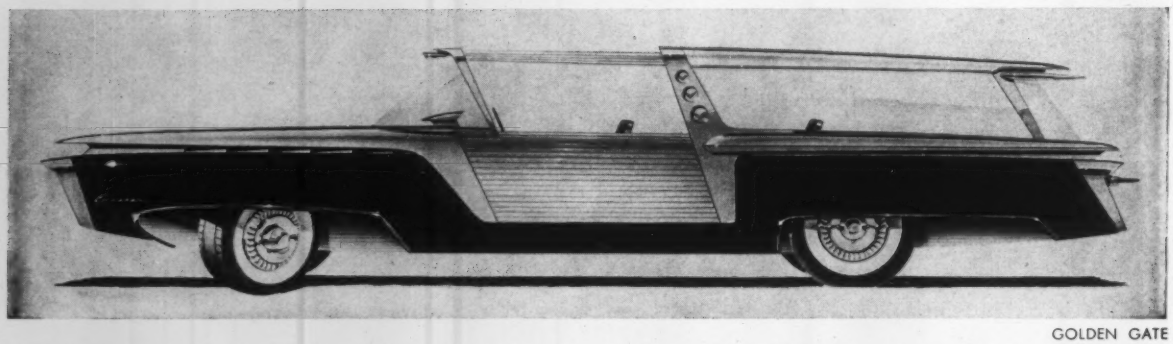
Circle 408 on page 19

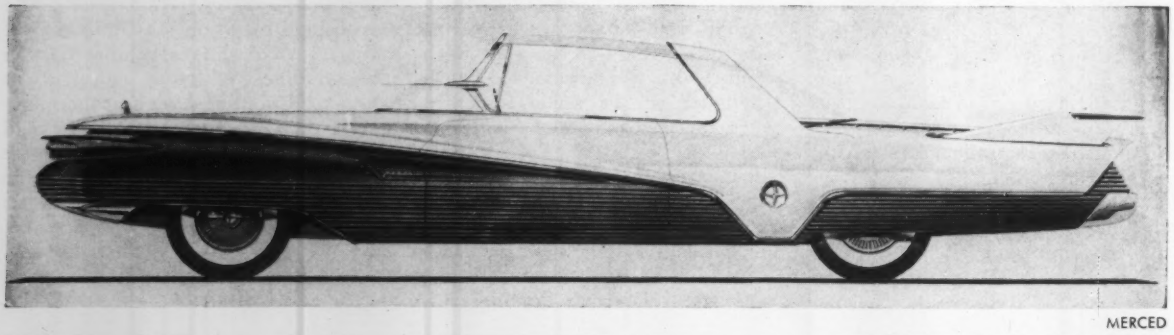


PIEDMONT



GOLDEN GATE

ROLL-AWAY HOOD, made of extruded aluminum panels joined by flexible plastic strips, is a feature for new passenger cars suggested by Kaiser Aluminum & Chemical Sales, Inc. Kaiser dreamed up the cars shown here to illustrate ways to extend the use of aluminum in automobiles. In addition to roll-away hood, all-aluminum "Piedmont" model has two-stage, three-piece, retractable hard top and roll-away, panel-type, rear deck cover. Exhaust mufflers are finned castings placed directly behind the front bumper. Front floor boards and seat risers are integral with cast frame. Exposed frame rails form a molding strip running the length of the car. "Golden Gate" station wagon has power-operated, roll-down doors and stamped wheel wells covered with colored vinyl. "Golden Gate" and "Merced" models have wheels, hubs and brake drums cast in one piece. The "Merced" roof opens as a roll-top hatch. Side panels can be stamped or extruded, color-anodized.



MERCED

Computer Is Programmed to Translate Four Languages

PASADENA, CALIF. — Translations from four different foreign languages into idiomatic English are accomplished by an electronic computer specially programmed for the job. Machine used is a Datatron made by ElectroData Div., Burroughs Corp. Multilingual engineer back of the development is Peter Toma of California Institute of Technology.

According to Toma, development of the translation technique is a significant advancement toward a universal interpretation of all the world's tongues. It is the only known technique formulated for multiple-language machine translation. The special Datatron not only produces a word-for-word record, but correctly renders the thought or sense behind each foreign phrase.

Datatron is prepared for trans-

FACTS

about

NEW DEPARTURE BALL BEARINGS

MAST-GUIDE BALL BEARING SIMPLIFIES DESIGN and LOWERS MAINTENANCE COST!

New Departure's mast-guide ball bearings bring lift truck designers greater variation in upright construction. These bearings eliminate sliding metal-to-metal contact and multiple bearings of complex design . . . as well as need for maintenance by the end user.

The mast-guide bearing is integrally sealed and lubricated for life. The heavy-section outer ring gives the added beam strength and shock resistance required for rugged duty. The extra width of the outer ring provides more contact surface to reduce mast brinelling. The hardened and ground "tire" is part of the bearing itself, resulting in lower cost for the lift truck manufacturer.

These bearings give the same advantages common to all New Departure ball bearings—unexcelled long-life performance in handling heavy combined loads . . . lowest operating friction for consequent improvement in horsepower efficiency. Also, there is no need for relubrication or adjustment throughout years of service.

Write for examples in *your* field where New Departure ball bearings and bearing engineering service help make good products better.

Photo: Courtesy of Clark Equipment Co.

BALL BEARINGS MAKE GOOD PRODUCTS BETTER

NEW DEPARTURE • DIVISION OF GENERAL MOTORS • BRISTOL, CONN.

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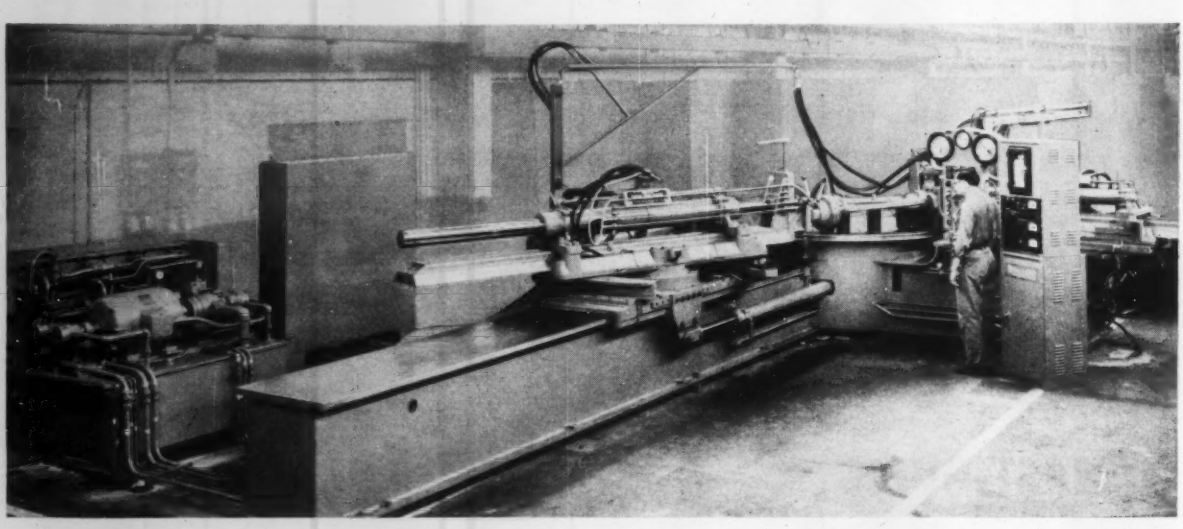


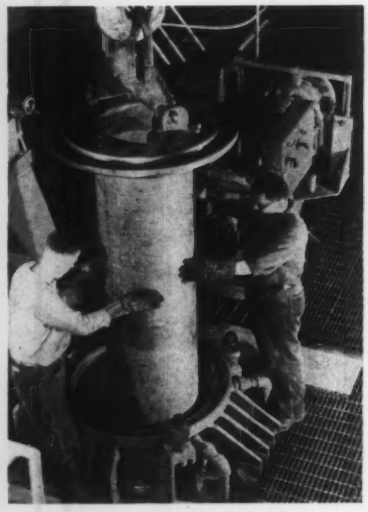
WORKPIECE IS ALSO TEST SPECIMEN in this radial draw-former equipped with Yield-Tension Monitor—products of the Cyril Bath Co. Electronically, the monitor determines the yield point of the material to be formed, then continuously controls the tension forces imposed during the forming operation. Close, continuous control insures against overstressing and breakage of products. Key feature is a load cell between the ram and the gripper head which holds the work. Signals derived from load cell readings control oil flow to the working cylinders and, in turn, the tension on the product being formed. Workpieces may have tapered length.

lating by first transmitting to its magnetic memory drum four specially-condensed dictionaries of Russian, French, German and Spanish. These have been punched on paper tape, in numerical computer language, along with instructions telling the computer how it should go about translating.

The computer converts the code into alphabetic characters, and compares various semantic and logical patterns with the pre-stored glossaries. In several minutes, it types out a complete page of English translation.

At present, each of the dictionaries contains about 500 words. External memories can be added to enlarge the vocabularies. Plans call for ten Burroughs Datafiles which can store 200 million characters of information.

Water-emulsion "safety" paint, containing no inflammable or fume-producing thinners, has been developed by Ford Motor Co. for use on automotive parts. Humidity and exposure tests indicate that the new paint equals durability of previously used materials.



REMARKABLE PURITY and unusual size of this 26-in, 12,000-lb ingot will make possible many new commercial applications. Turbine wheels, landing gear parts and similar components can be made in larger sections having greater strength. High-alloy steel ingot was produced in consumable electrode furnace by vacuum melting process. Allegheny Ludlum Steel Corp. will also use furnace to melt titanium, zirconium and wide range of ferrous and nonferrous alloys.

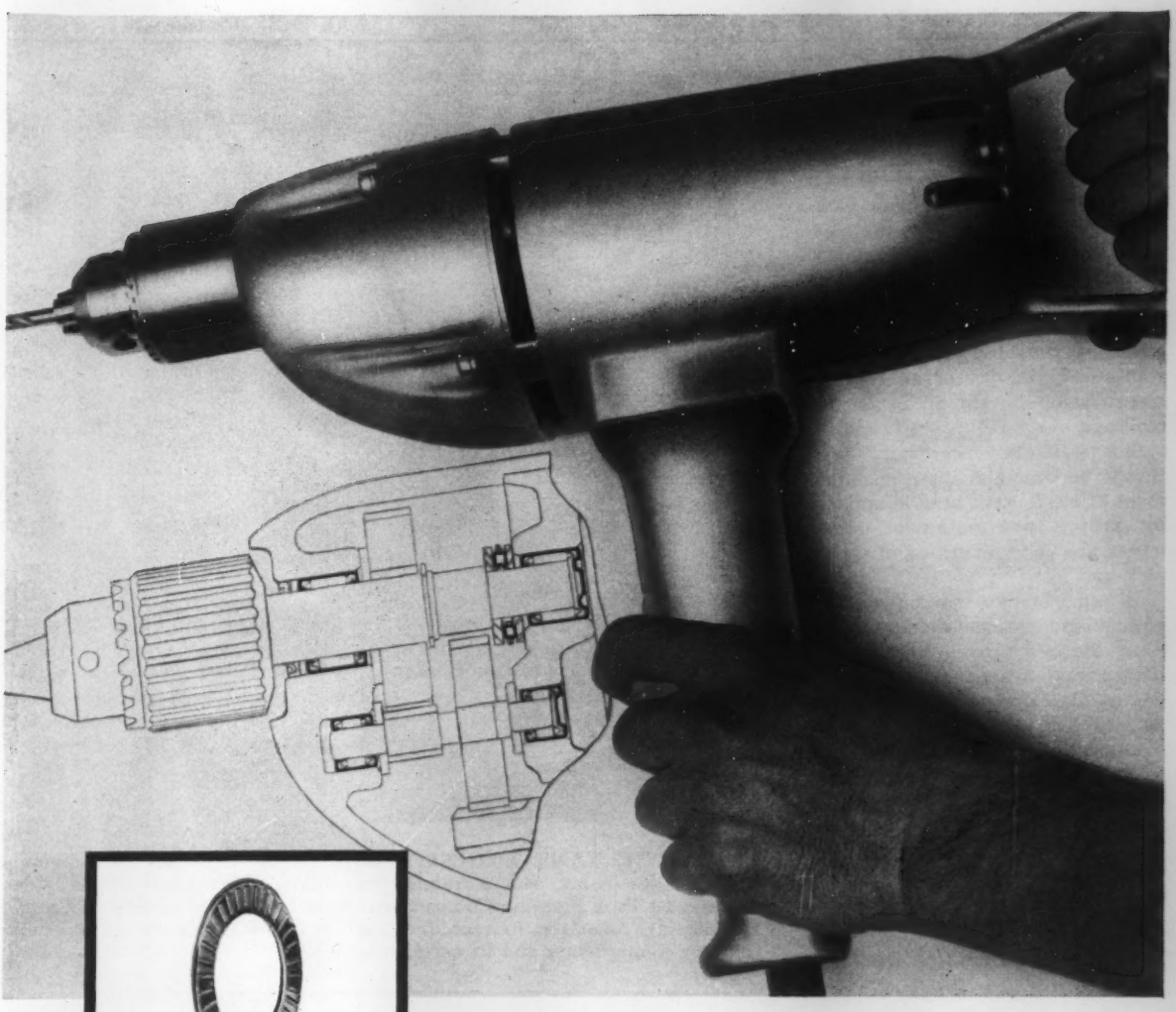
Inertia Wheel Simulates Car, Tests Engine, Parts Design

New Device Helps Engineers Reduce Road-Testing Time

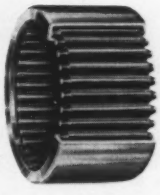
PHILADELPHIA, PA.—New method of measuring engine and transmission variables and their influence on performance has been developed by Ford Motor Co. Called inertia-wheel testing, the process greatly reduces actual road testing of engines and transmissions, and is said to be cheaper, faster and more accurate.

Inertia wheel is a specially constructed flywheel preloaded so its rotating mass simulates the total inertial forces of the particular car for which engine under test is designed. When engine and transmission are accelerated, the wheel offers the same resistance to changes in engine speed as moving vehicle would. Performance variations are measured by torquemeters responsive to 17,500 torque pulsations per minute—maximum firing rate of an eight-cylinder engine.

Torquemeters, developed by Baldwin-Lima-Hamilton Corp., consist of four electric strain gages bonded



For thrust loads
Torrington
Needle Thrust Bearing



For radial loads
Torrington Needle Bearing

Made for each other...

Where you want to handle high radial and thrust loads in minimum space, you'll find that Torrington Needle Bearings and Needle Thrust Bearings go together like nuts and bolts.

Full complement Needle Bearings handle higher radial loads than any other anti-friction bearing of comparable size. Needle Thrust Bearings are washer-thin—only .0781" thick—complementing radial-type Needle Bearings in providing high thrust capacity in minimum space. Used together, these Torrington bearings contribute to compact design, light weight, maximum capacity and long service life.

Both bearings can operate on hardened and ground adjacent parts, or can be used with standard races. Our engineering staff will be glad to help you make the most of this efficient combination in your thrust and radial load applications. **The Torrington Company, Torrington, Conn.—and South Bend 21, Ind.**

TORRINGTON BEARINGS

District Offices and Distributors in Principal Cities of United States and Canada

NEEDLE • SPHERICAL ROLLER • TAPERED ROLLER • CYLINDRICAL ROLLER • BALL • NEEDLE ROLLERS • THRUST

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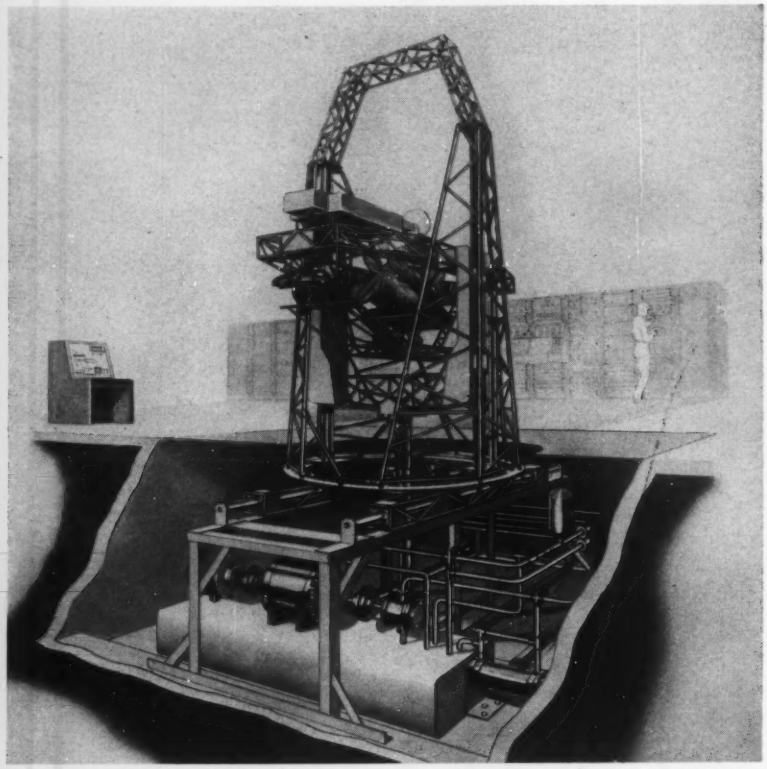
to a steel shaft 18 in. long and connected in a Wheatstone bridge circuit. When change occurs in engine or transmission speed, the torquemeter shaft is subjected to a twisting moment. Strain-gage pickups translate twist into an electrical signal exactly proportional to induced torque. Signal from pickup is amplified and fed to a recording oscillograph. This instrument provides continuous, instantaneous record of engine and transmission output in 0.1-second readings.

Side effects resulting from thrust, bending and slight misalignment of shaft have been eliminated by proper positioning of strain gages and rigid mounting of torque pick-up.

In addition to testing specific engine and transmission performance, the new process has aided in design and evaluation of various engine components and car accessories. For example, effects of air conditioning compressors on engine performance have been noted. Other studies have concerned cam timing and distributor calibration.



AUTOMATIC TANK ENGINEER helps human engineers in designing tanks for the Army. Not a training instrument, the unusual device is described as a Tank Fighting Compartment Simulator. It was devised by Lehigh Engineering Associates to reproduce various forces which act upon a tank fighting compartment and its occupants.

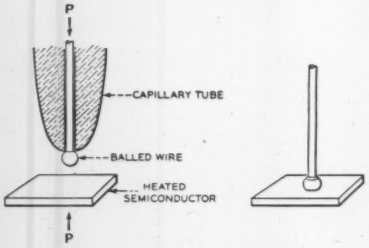
Bond Leads to Semiconductors By New Process, Quick, Simple

Mass Production Use Seen For Thermocompression

NEW YORK, N.Y.—Leads are attached to semiconductor devices at Bell Telephone Laboratories by a new technique that involves heat and pressure but nothing else. Firm bonds are made between various soft metals and clean, single-crystal, semiconductor surfaces.

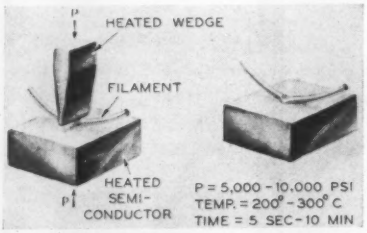
Called thermocompression bonding, the new technique provides a bond that is stronger than the lead itself. Temperatures and pressures required are not high enough to affect the electrical properties of the semiconductor material.

Adhesion takes place in seconds with pressures of a few thousand psi and temperatures well below the melting point of the alloy of the metal and semiconductor. A gold-germanium bond appears to be the easiest to make, but gold, silver, aluminum and a number of alloys can be readily bonded to either germanium or silicon.



With thermocompression technique, connection is made by butting the headed end of a wire against a heated semiconductor.

According to the Bell Labs, thermocompression bonding has a number of advantages over other methods of attaching leads to semiconductors. The bond is stronger; the technique is more readily adaptable to mass production; no chemical flux or other chemical contaminant is involved in the process; and leads may be attached to much smaller areas, an invaluable aid in fabricating high-frequency transistors.



In this method of thermocompression bonding, a heated wedge presses a lead against a semiconductor, also heated, with enough pressure to deform the lead metal. Adhesion occurs in seconds.

Brightest Lighting System Non-Glare Aid to Production

CLEVELAND, O.—Industrial lighting system claimed to produce a level of illumination three times greater than any in existence is announced by General Electric Co. An experimental installation at the company's Nela Park Div. attains more than 1000 ft-c of illumination, compared to the usual 100-200 ft-c industrial installation.

Responsible for the increase is a new aluminum reflector and louver used in conjunction with high-frequency fluorescent tubes. Mounted on white enamel channel, louvers are wedge shaped in cross-section and the fixture has 35-degree shielding for both cross and lengthwise viewing. The new system is said to solve problem of providing visual comfort at very high lighting levels.

Office Paper Work Speeded By New Automated Typewriter

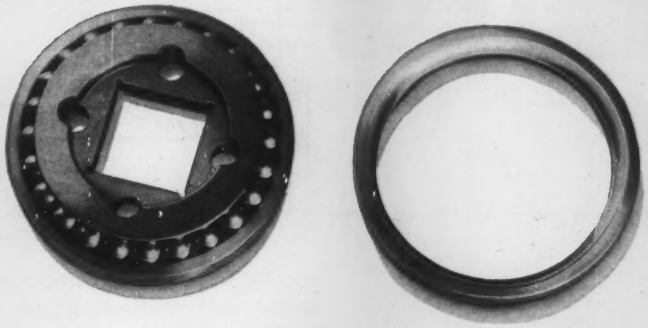
NEW YORK, N.Y.—Major advance in office automation is claimed through recently introduced electronic, punched-tape typewriter. New machine, developed by Remington Rand, automatically creates and reads paper tape that activates other electronic office equipment.

When used as an ordinary electric typewriter in preparing source documents, all typewritten material is simultaneously translated into punched tape for subsequent processing. When the same tape, or tape prepared from other machines, is fed into the typewriter, it reads and types out the information at rate of 120 words per minute.

The machine can be adapted to various data-processing programs with building-block flexibility. Three basic models—tape punching unit, tape reading unit, and unit that does both—make possible the arrangement of equipment according to specific needs of each department in the overall data-processing scheme. Type-

(*Continued on Page 22*)

Square-Hole Ball Bearing Simplifies Antenna Design



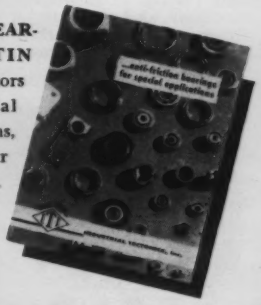
This radar bearing, 1.500" OD, carries 3000 lb. thrust while turning through 180° at 90 oscillations per minute. The split outer race permits larger ball complement and increased load capacity.

In planning the mechanical design of a radar antenna, the designer found that by using a ball bearing with a square hole, he could avoid limitations imposed by standard bearings. To bring this dream to reality, he had Industrial Tectonics design and produce the special bearing shown above. This has resulted in (1) a simpler and less costly design of the assembly that the bearing carries, and (2) a stronger and more rigid support.

In this and many other ways, the availability of ITI special bearings permits new freedom of design, and new economy. Remember —

IF YOU need anti-friction bearings of *special shape, size, heat resistance, corrosion resistance, low torque, ultra precision, non-magnetic properties, or other unusual characteristics,* we can supply them — designed and built to your specific requirements. We invite your inquiries.

FREE 32-PAGE BEARINGS BULLETIN tells about the factors involved in special bearing applications, and describes our work in this field. *Write for Bulletin AFB-1.*



INDUSTRIAL TECTONICS, Inc.

ITI

MANUFACTURERS OF PRECISION BALLS AND BEARINGS

3699 JACKSON RD., ANN ARBOR, MICH.

WESTERN DIVISION PLANT: COMPTON, CALIFORNIA

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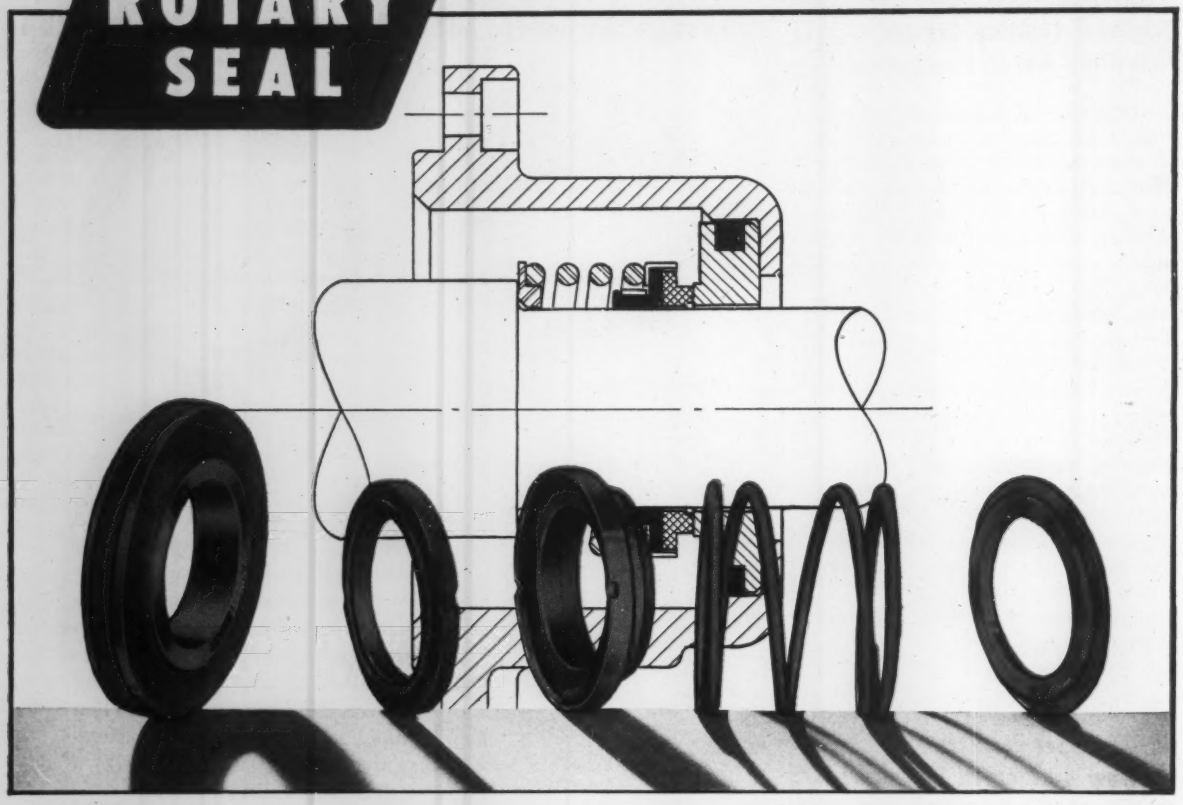
ROTARY SEAL

SPECIALIZED SEAL ENGINEERING



is developing new ways to assure top performance in COMMERCIAL AIR CONDITIONING EQUIPMENT

The operating conditions of a heavy-duty commercial air conditioning compressor unit are tough for ordinary Shaft Seals to handle. The combination of high operating speed and pressure is conducive to high heat generation—and that, in turn, can lead to Seal failure and unit breakdown.

The sound design of ROTARY SEALS—properly adapted to the particular conditions of this application—removes most of the major cause of such failures, without requiring complicated unit design. With this sturdy Seal, heat dissipation is excellent, and even under the severe operating conditions, heat generation is effectively reduced. Net result: greater customer satisfaction, elimination of trouble and expense through constant service calls.

The ROTARY SEAL illustrated was specially developed to meet this exact requirement. You can't just reach back on the shelf for a Shaft Seal when your compressor—or pump, tractor or whatever your unit may be—must measure up to unusual or especially taxing job requirements. It takes a *custom-designed* Seal—fitted in every detail to the specific job at hand.

ROTARY SEAL specializes in developing and manufacturing Seals to meet such problems, by applying the basic ROTARY SEAL principles which opened the way to successful mechanical Shaft Sealing when this company introduced them years ago.

The best time to start solving your Shaft-Sealing problem is at the drawing-board stage. Call in our engineers for an early consultation—our experience with Seal applications of all kinds in many fields often indicates suggestions which can simplify design, lower costs and improve performance.

Shaft-Sealing with Certainty

ROTARY SEAL DIVISION

MUSKEGON PISTON RING CO., SPARTA, MICHIGAN

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USE A YELLOW CARD *for More Information . . .*

CIRCLE ITEM NUMBERS—Throughout the magazine, each advertisement carries an Item Number for use in requesting further information. All product descriptions, announcements and Helpful Literature items are also numbered, and for greater convenience are indexed below by Item Numbers.

EDITORIAL CLIPSHEETS—So you won't have to "clip" this issue, we'll be glad to send a personal copy of any article as long as the supply lasts. Just fill in the page number and title of article in the place provided on the Yellow Card.

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AUGUST 8, 1957

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403	428	453	478	503	528	553	578	603	628	653	678	703	728	753
404	429	454	479	504	529	554	579	604	629	654	679	704	729	754
405	430	455	480	505	530	555	580	605	630	655	680	705	730	755
406	431	456	481	506	531	556	581	606	631	656	681	706	731	756
407	432	457	482	507	532	557	582	607	632	657	682	707	732	757
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413	438	463	488	513	538	563	588	613	638	663	688	713	738	763
414	439	464	489	514	539	564	589	614	639	664	689	714	739	764
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416	441	466	491	516	541	566	591	616	641	666	691	716	741	766
417	442	467	492	517	542	567	592	617	642	667	692	717	742	767
418	443	468	493	518	543	568	593	618	643	668	693	718	743	768
419	444	469	494	519	544	569	594	619	644	669	694	719	744	769
420	445	470	495	520	545	570	595	620	645	670	695	720	745	770
421	446	471	496	521	546	571	596	621	646	671	696	721	746	771
422	447	472	497	522	547	572	597	622	647	672	697	722	747	772
423	448	473	498	523	548	573	598	623	648	673	698	723	748	773
424	449	474	499	524	549	574	599	624	649	674	699	724	749	774
425	450	475	500	525	550	575	600	625	650	675	700	725	750	775

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401	426	451	476	501	526	551	576	601	626	651	676	701	726	751
402	427	452	477	502	527	552	577	602	627	652	677	702	727	752
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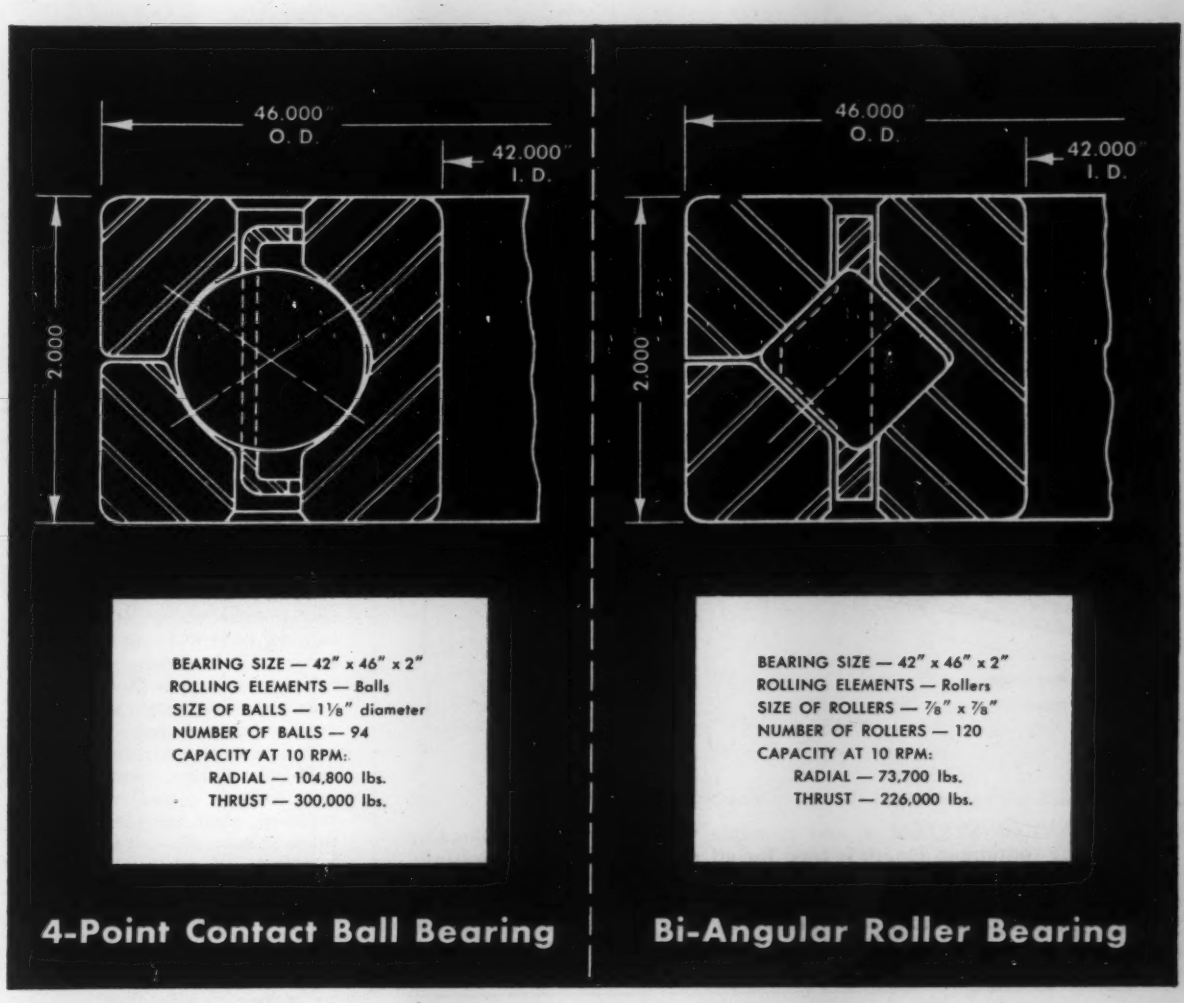


SURE we make both, but we recommend only one

Yes, Kaydon manufactures both — 4-point contact ball and bi-angular roller bearings in the same diameters and widths. BUT—we would in almost every instance recommend the former. Why? Because our field application reports consistently prove that the 4-point contact ball bearings are better for most applications than the lower capacity bi-angulars *(See capacity figures in drawings above.)*

Another important difference between the two bearings is that the 4-point contact ball bearing *is not limited to low speeds,* whereas the bi-angular normally should not be used above 10 rpm and usually is suitable only for oscillation. Then, too, the torque in the 4-point contact ball bearings is generally much lower.

Kaydon's unbiased recommendations result from years of bearing design, application and manufacturing experience with *all types* of ball and roller bearings up to 124" in diameter. So, why not contact Kaydon first?

K-563

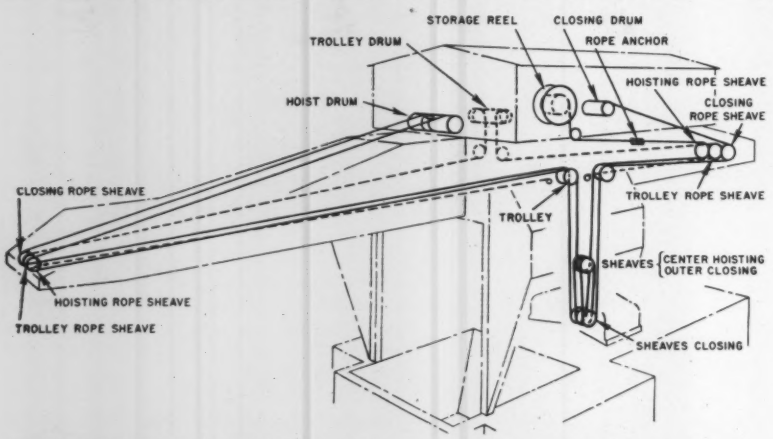
THE KAYDON ENGINEERING CORP.

MUSKEGON • MICHIGAN

All types of ball and roller bearings — 4" to 120" outside diameter . . .
Taper Roller • Roller Thrust • Roller Radial • Bi-Angular Roller • Needle Roller • Ball Radial • Ball Thrust Bearings.

(*Continued from Page* 15)
writer speeds input and output to and from a centralized processing system, permitting automation in handling basic paper work.

As a typical example, when an order for merchandise is received, customer's master tape is removed from files and used to type sales order automatically, with manual insertions of variable data. Simultaneously, new tape is being punched which may be later used to prepare the shipping advice. Tape prepared from typing the sales order can be used to produce an invoice and to create punched cards for tabulating invoice records, sales analysis, and other data.



NEW REEVING SYSTEM is said to triple wire rope life on unloading towers. One continuous length is used for all normal independent hoisting, closing and trolley motions. Wear at points of contact—sheaves, rollers, drums—is spread evenly throughout entire rope length by method of progressively feeding new rope into the system from storage reel. Progressive Reeving System is development of Mead Morrison Div., McKiernan-Terry.

Welding of Magnesium Speeded By Improving Old Technique

CLEVELAND, O.—New device that permits automatic, continuous welding of magnesium and eliminates frequent "burn backs" has been developed by Copperloy Corp. Increased welding speeds and greater weld penetration are also claimed.

Shielded inert-arc, consumable-electrode process is used, employing small diameter coiled wire as both filler metal and electrode. Continuous welds up to 30 ft in length are said to be routine. Welds on various magnesium parts, ranging in cross-section from ⅛-in. to heavy plate, structural shapes and castings, have been performed successfully. Device is claimed to be equally effective in welding aluminum.

Longest Civil Microwave System Jumps Mountain on One Relay

EL PASO, TEX.—Longest reflected microwave "hop" in U.S. private industry has been built into a new communication installation recently completed by General Electric Co. for El Paso Electric Company. The "bouncing microwave" system achieves reliable communication over a 40-mile distance by using mirror-like reflectors as relays instead of regular repeater stations.

The system is capable of handling private conversations, printed material and remote control signals. Primary use will be to transmit information on the flow of power between El Paso Electric Company and interconnected companies. It will provide more efficient supervisory control of the Las Cruces substation from the

Metals Matters

New titanium alloy said to offer improved high temperature strength, excellent time-temperature-strength stability and improved heat treated properties, is announced by Rem-Cru Titanium Inc. Alloy has composition of 6½ per cent aluminum, 3¾ per cent molybdenum. Samples of the new alloy exposed to high stress in 600 to 1000 F range show undiminished strength and good ductility in subsequent room-temperature tensile tests. Tensile strengths exceeding 160,000 psi with good ductility in heat treated sections over 2 in. thick have been secured in laboratory.

• • •

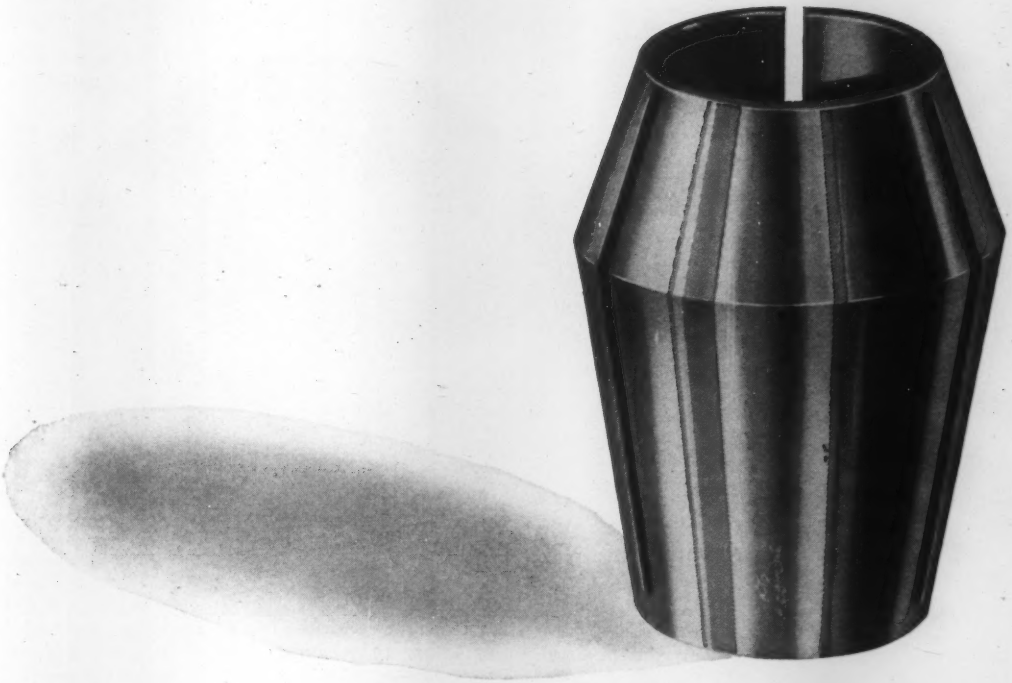
Black stainless steel is being used in construction of new office building to provide contrasting exterior trim. Ebonizing process, developed by Armco Steel Co., consists of immersing stainless in molten bath of dichromates. Result is smooth, permanent, black-oxide film having corrosion-resistant features equal to original stainless steel surface. Ebonized finish is naturally flat in tone, can be made glossy by waxing or oiling.

• • •

Extrusion of molybdenum tubing is result of new process developed by Wolverine Tube Div., Calumet & Hecla Corp. High strength of the material at extrusion temperatures has been obstacle to previous commercial extrusion. Tubing for evaluation purposes is available in following dimensions: less than 1 in. OD, 0.1-in. wall thickness, 3 to 6 ft in length. Tensile strength is 70,000 to 100,000 psi; yield strength, 60,000 to 90,000 psi.

• • •

Welding fittings of zirconium and Zircaloy 2 have been forged —perhaps for the first time—by Tube Turns Div., National Cylinder Gas Co. The fittings have an outside diameter of 1.5 in. and a 0.065-in. wall. In addition to providing excellent resistance against a wide variety of corrodents, the fittings have a very low thermal cross section (0.18-Barn), and are said to possess relatively good strength up to moderately high temperatures. The metals also have a high degree of stability under radiation.



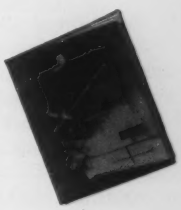
19% PRODUCTION INCREASE AND SUPERIOR FINISH

when Universal Engineering Co. switched to

LEADED 6150

In the production of this collet, Universal Engineering Co. reported it was able to increase spindle speed from 308 to 374 R.P.M. and machine speed from 108 to 125 S.F.M. Feed was stepped up from .0027 to .0047 inch per revolution. In addition to a production increase from 101 to 120 pieces per hour, finish was greatly improved and tool life was extended appreciably.

These are typical benefits obtained by users of lead treated Aristoloy Steels—benefits which you can enjoy by getting in touch with your nearest Copperweld district office.



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ARISTOLOY STEELS

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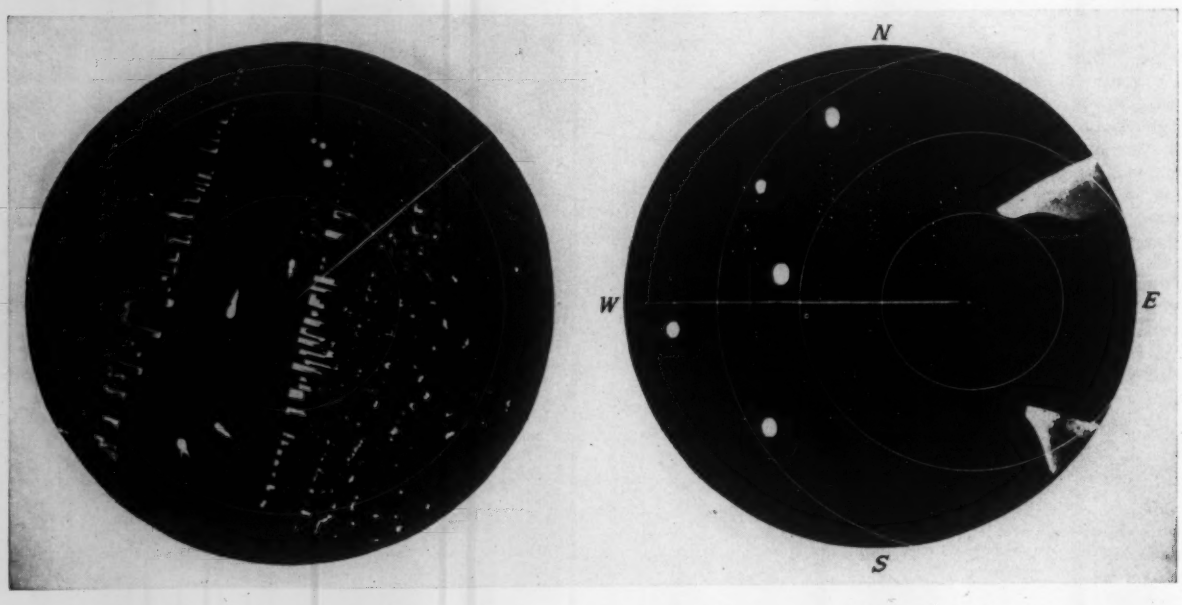


TRUE TRACKING RADAR, most recent aid to marine navigation developed by Sperry Gyroscope Co., gives panoramic picture, *above, left,* which includes the ship in which it is installed. Stationary objects stay fixed on scope. Moving objects have glowing tails by which their course of travel and speed can be estimated. Off-center positioning device, also new, enables navigators to position their ships anywhere in the radar display, *above, right.* By positioning the movable sweep center, observer can scan beyond the display's original range without changing the display scale. Uses are traffic control and coastal navigation.

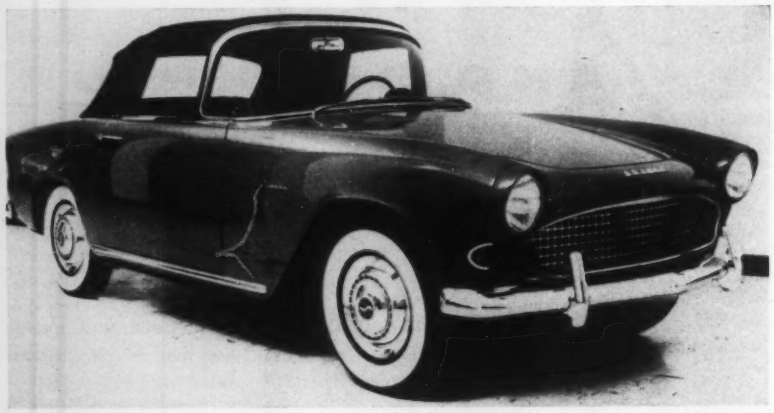
dispatcher's office in El Paso.

Builders of the system faced difficult terrain problems. The point of origin was 150 ft lower than the surrounding terrain and the electrical utility wanted to avoid the expense of high towers and the problem of acquiring real estate for guying areas.

In the completed installation, a 14-ft steel mesh dish is placed at a 55-ft elevation at the Rio Grande plant. A 20-ft square aluminum reflector is located on Mount Cristo Rey 4400 ft above sea level. A 14-ft dish is placed at a point 80 ft high at the main Las Cruces substation.

The mountain reflector is $\frac{1}{4}$-in. thick and is peppered with holes to make it less resistant to winds as high as 125 mph. Acting like a mirror in relaying microwave signals, the reflector eliminates the need for repeater towers between stations.

The system is designed to improve the company's speed in restoring service after outages caused by storms and other factors.



Simca Sport Convertible features 57 hp engine, unitized construction, wrap-around windshield, two-tone color combination, optional reclining seats.

Simca Autos From France Claim Comfort Plus Economy

NEW YORK, N.Y.—Typical of the Simca line of small French automobiles available in U.S. is the five-passenger Arronde series comprising six body styles. Series includes four-door sedans, two door hardtops, station wagon and sports convertible. All models

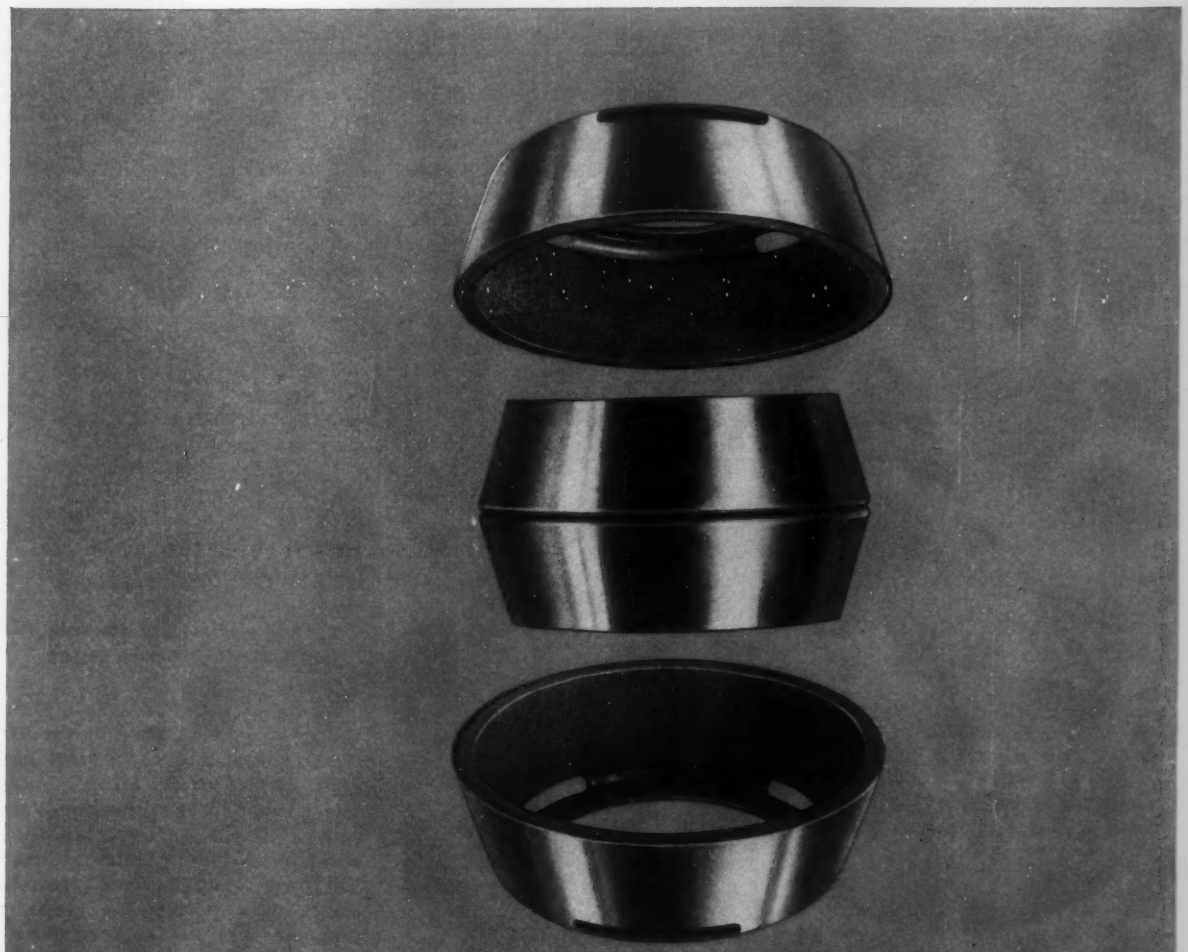
Engine Specifications

Type	In-line, OHV
No. cyls.	4
Bore & stroke (mm)	74 x 75
Displ. (cc)	1290
Comp. ratio	6.8 to 1; 7.8 to 1
Bhp, max	48; 57 @ 5200

Dimensions

Wheelbase (in.)	96
Length (in.)	158; 162; 168*
Width (in.)	61.2
Height (in.)	54.7; 60.6*
Weight (lb)	2050; 2127*

*Depending on body style.



Resilient clutch facings smooth up power tool operation

The double-cone tapper clutch shown here transmits power efficiently under widely varying conditions of facing pressures and speeds. And it runs smoothly and quietly, without the vibration or chatter that can break taps or spoil precision work.

The clutch facing that does this job is Armstrong NC-733, a resilient friction material that can be operated either dry or immersed in oil. This facing delivers the torque capacity needed for tapping holes up to 1½" diameter in steel plate. And it picks up the torque instantly, at any tapping speed.

Another advantage of this resilient facing is its sensitivity to the performance of the tap, even on delicate work where facing pressures are usually low. The operator can immediately detect a dull or overloaded tap.

NC-733 is economical, too, both in first cost and long service life. In most applications, it will remain fully serviceable for several million engagements.

NC-733 is one of a wide range of Armstrong resilient friction materials that are being used in both wet and dry applications in many fields . . . including industrial and office equipment, appliances, and automotive transmissions. For more information, write to Armstrong Cork Company, Industrial Division, 7208 Dean St., Lancaster, Penna.

Armstrong RESILIENT FRICTION MATERIALS

. . . used wherever performance counts

Circle 415 on page 19

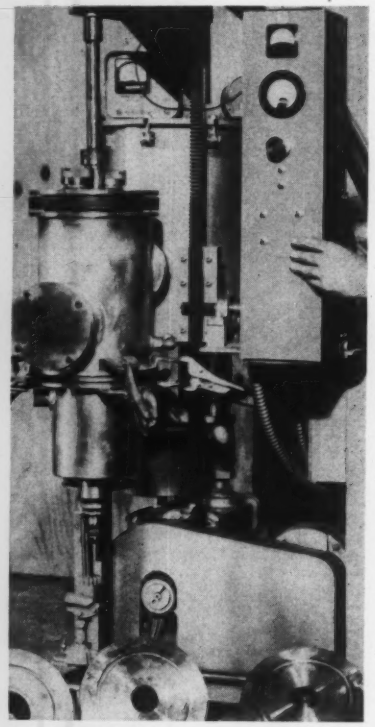
are powered by choice of 48 or 57 hp, four-cylinder OHV engine.

Heater and defroster are standard equipment. Standard transmission has four forward speeds with control lever on steering column. Electromechanical, automatic transmission is optionally available. Engine features include automatic choke and spark advance and 12-v electrical system. Various two-tone exterior finishes are offered with contrasting vinyl, cloth, or leather interiors.

Car is said to have good riding and handling qualities for its size due to fairly massive suspension system. Rear semielliptic springs are 42 in. long, have eight leaves each plus two 5/16-in. overload leaves. Each spring has 1¾-in. double-acting tubular shock absorber.

Unitized body-frame structure of pressed steel is welded throughout.

Cylinder head, transmission and bell housing, various chassis parts body hardware, external trim and wheel covers are aluminum.



NEW RESEARCH FURNACE, commercially available, for vacuum melting of titanium, zirconium, columbium and other metals that require controlled-atmosphere melting, is produced by Oregon Metallurgical Corp. Furnace is designed to produce standard 1½-in. diam, ½-in. deep evaluation button by arc melting of sponge or shavings. Ingots from 2 to 6-in. diam, ranging in length to 16 in., can also be produced by consumable electrode process. Molds are contained in water-cooled copper crucible and furnace can be pressure back filled with argon or helium.

New High Energy Fuels Now in Use by Air Force

Turbojets, Ramjets, Rockets Go Faster, Farther on Boron

NIAGARA FALLS, N.Y.—New high-energy fuels being used by the Air Force are claimed to increase aircraft range up to 50 per cent. The boron-hydrogen combinations, called HEF-2 and HEF-3, are being produced by Olin Mathieson Chemical Corp. after five years research, two years production testing. Company claims that more powerful fuels are ready for production when needed by the Air Force.

Compared to present aviation gasoline, which has heating value of about 19,000 Btu per lb, new fuels range upward from 25,000 Btu.

In addition to increasing range, high energy fuels will permit use of smaller, lighter engines, i.e., length of ramjet engine is partially determined by space and time required for fuel-air mixture to burn as it passes through engine. New fuels achieve complete combustion in much less time, permitting use of shorter combustion chamber. High efficiency of the fuels also eliminates problem of flame-out in jet engines.

Commercial use of the new fuels is reportedly ten years in the future due to production costs, although remarkable performance gains possible will undoubtedly cause considerable demand.

The fuels can be handled, stored and shipped safely.

Eliminate "high-cost specials" by standardizing on

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Investigate and you'll probably find that instead of having to go to the added time and expense of ordering special gears, that your needs can be filled from the American line.

American is a complete stock gear line. It includes brass, bronze, steel, semi-steel, cast iron, and non-metallic gears in a range of 48 to 3 diametral pitch. Available from your nearby distributor of American Stock Gears.

Ask for FREE copy of American Stock Gear Catalog No. 368 containing detailed information and engineering data.

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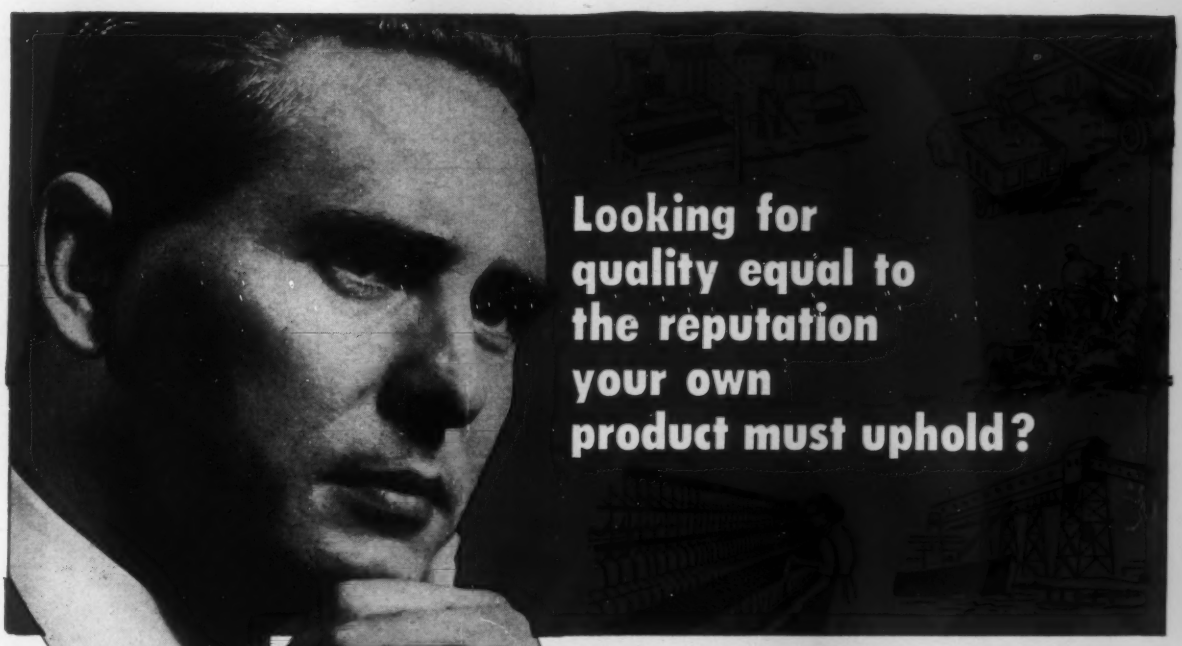

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EXCLUSIVE COMBINATION OF FEATURES ASSURES NEW HIGH STANDARDS OF BEARING PERFORMANCE

Today, a designer who wants to get the most out of his product must look on components as part of his overall design. The fact that a bearing unit is just as essential to modern high performance and can cause failure of an otherwise perfectly engineered machine is reason enough for specific SEALMASTER recommendations. Each year as machinery gets faster, horsepower greater and manpower more costly, "downtime" becomes more critical.

No component you specify for the products you design or build will be of more dependable quality than SEALMASTER Ball Bearing Units. From design board to finished product SEALMASTER Bearings are the product of "Quality-minded" engineering and manufacturing processes backed by an exclusive combination of features. Find out today how important SEALMASTER Ball Bearing Units are to you!

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Choosing the carbon brushes that are supremely suited to your requirements is easy when you have the book that tells you all about brush characteristics and applications. Covering brushes for every type of fractional horsepower, automotive, aviation and industrial application, it represents 50 years of carbon and brush leadership. Its title? "Brushes by Speer."

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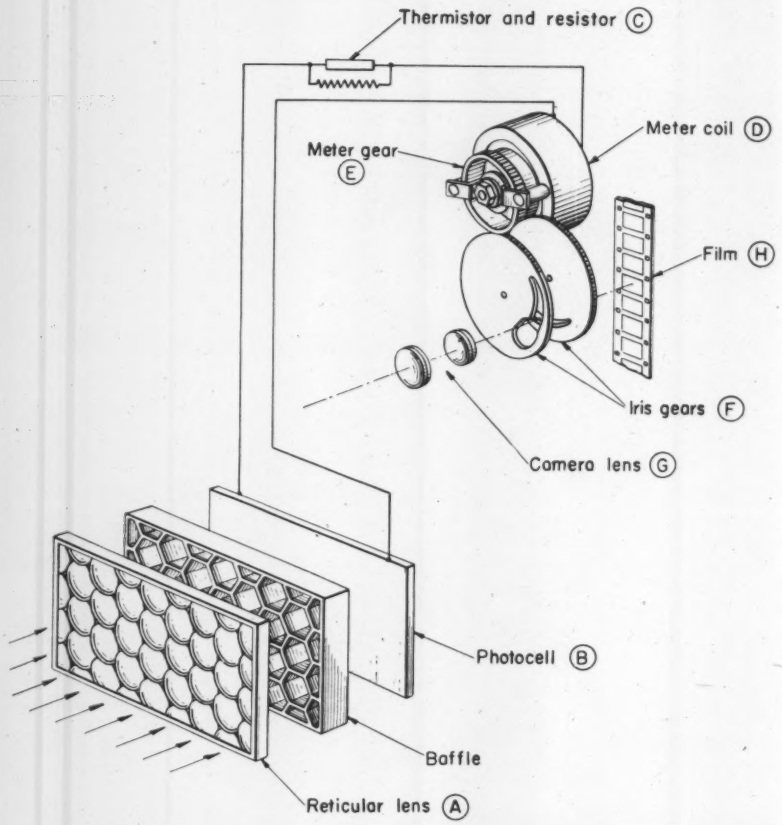
Circle 418 on page 19



In the Bell & Howell automatic exposure setting mechanism, light passes through a reticular lens *A* and baffle which match angular coverage to the film lens coverage. Photocell *B* generates current which passes through thermistor and resistor *C* where it is compensated for temperature variations. Current deflects meter *D* which rotates gear *E*. Iris gears *F*, turned by meter gear, have openings shaped to control and vary light passed through camera lens *G* to film *H*. Response between range limits is 1 sec.

Light Alone Sets Camera Lens Automatically

Rugged Setting Device Also Compensates for Temperature

CHICAGO, ILL. — Light from subjects being photographed powers a device which automatically sets lens exposure in a new Bell & Howell movie camera.

The new camera is claimed to be the first in the world in which light energy alone supplies the power to adjust the lens. No batteries, motors or springs are used for this setting. The current is transmitted directly from a photoelectric cell to the lens controls. The control mechanism can operate through a range of lens stops from f/1.9 to f/16 under 1 sec.

No focusing is necessary, and the camera can be used with indoor or outdoor color film. The operator need only wind the camera, sight and shoot. He can follow a subject from light to shadow, assured that the electric eye is compensating for the light changes.

An amber exposure beacon in the camera's viewfinder glows as long as the available illumination is adequate. It turns black to signal that there is insufficient light for movie making.

Through the use of thermistors, the electric eye mechanism adjusts to temperature changes. The camera can be used at any tempera-

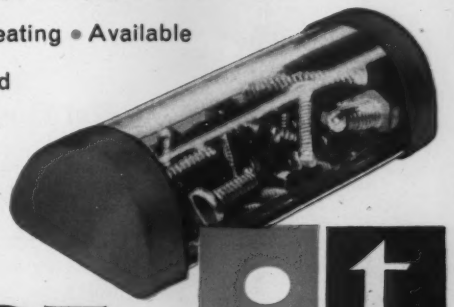
Tap and Fasten

in one operation

Immediate savings in time and money assured!

Special points, special heads, and special-purpose screws incorporating the Shakeproof Thread-Cutting slot provide added cost-cutting advantages.

• End separate tapping costs • Shakeproof Thread-Cutting Screws cut perfectly mated threads • Available in three styles for metals, die-castings and plastics • Can be removed and re-used • Extra strength due to heat treating • Available in all standard head styles, pre-assembled as Sems, and in many special application designs as shown above.



Write for sample kit containing Shakeproof Thread-Cutting Screw assortment

SHAKEPROOF

"FASTENING HEADQUARTERS"®

DIVISION OF ILLINOIS TOOL WORKS

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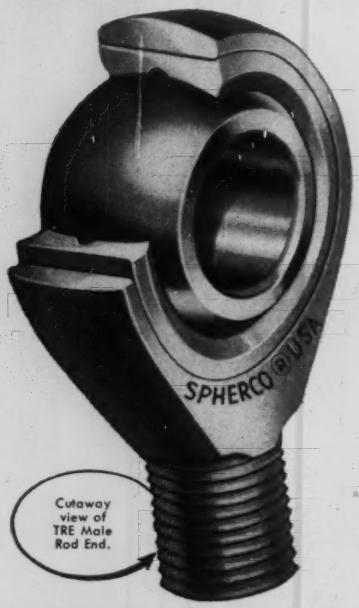
In Canada: SHAKEPROOF-FASTEX, Division of Canada Illinois Tools, Ltd., Toronto, Ontario

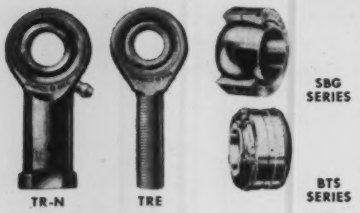
Circle 419 on page 19

YOU CAN DEPEND ON
SPHERCO®
BEARINGS & ROD ENDS



Quality SPHERCO Bearings and Rod Ends are precision built for superior performance

There are SPHERCO Bearings and Rod Ends for every application! There is a SPHERCO Engineer in your area to help you with your problems.



YOU'LL WANT FULL INFORMATION ON SPHERCO FEATURES . . . WRITE TODAY FOR THIS NEW CATALOG

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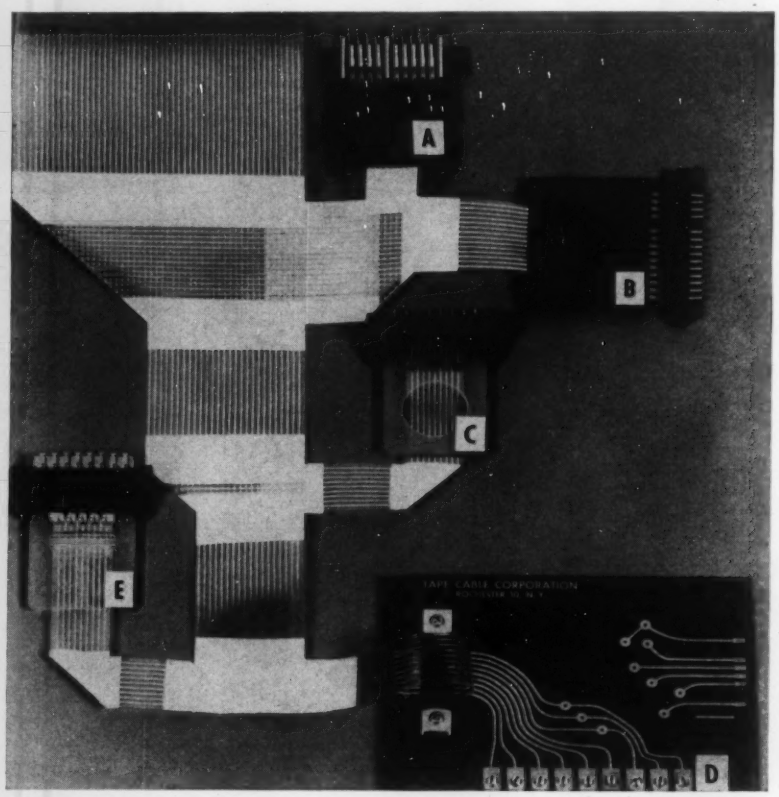
A PRODUCT OF
SEALMASTER BEARING DIVISION
STEPHENS-ADAMSON MFG. CO.
18 RIDGEWAY AVE. • AURORA, ILL.

Circle 420 on page 19

ture extremes the film itself will withstand.

The camera can also be operated manually. Turning a dial from "auto" to "manual" disconnects the automatic exposure control so that the lens may be set for special effects.



Typical application of 50-conductor Tape Cable in harness. *A* shows 9-contact plug with rubber sleeve, wedge strain relief and Cinch connector. *B* shows 14-contact plug with rubber sleeve, wedge strain relief and Amphenol connector. *C* demonstrates use of 9-contact plug and connector. *D* shows 9-contact printed circuit board with bar strain and Tinnerman nuts for making wire connection. *E* shows 9-contact Elco plug and connector.

Flat Conductors in Plastic Tape Form Electrical Cable

Lightweight Multiconductor Is Flexible Space-Saver

ROCHESTER, N. Y. — Electrical cable in tape form, claimed to allow new concepts in design of electrical and electronic circuitry, has been developed by Tape Cable Corp.

New product consists of flat copper conductors 0.03-in. thick, 0.0015-in. wide, embedded in film of transparent, flexible polyester insulation. Each conductor is rated at 1 amp, 300 v. Cable has exceptionally small cross-sectional area—0.011-in.—and offers low interconductor capacitance, high tear strength, high flex life and resistance to chemical attack.

It is available in nine standard sizes containing from 9 to 50 conductors. Center-to-center spacing of conductors is 0.1-in., complying with RETMA grid pattern for printed wiring.

Wiring density of 1160 conductors per cross-section sq in. is possible with Tape Cable, compared to 225 conductors per sq in.

GOLD-N-RING ... a new name and a new conception of CONTROL SWITCH design

HEAVY-DUTY

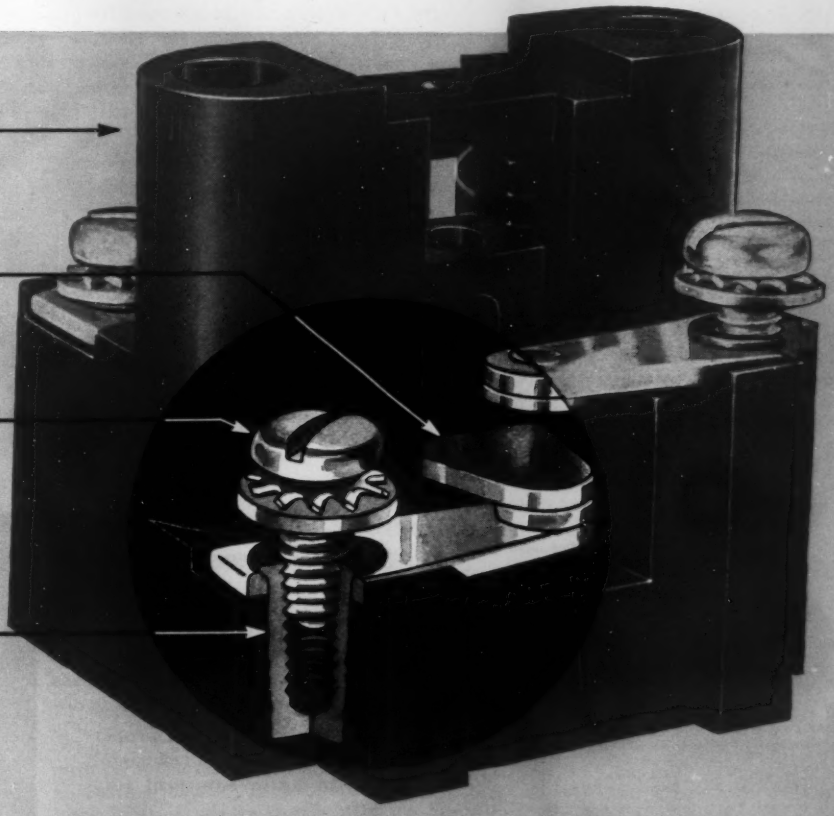
OIL-TIGHT—WATER-TIGHT—DUST-TIGHT

made by machine tool builders to machine tool specifications

A new name—GOLD-N-RING Sealtight Control Switch! A new conception—a control switch *designed and built BY a manufacturer of machine tools—FOR machine tool builders!*

A product of the same machine tool background responsible for Namco Solenoids and Snap-Lock Limit Switches, it gives designers a *package of greater electrical efficiency*—available from a single source, with a single source responsibility.

Shown here are only a few of many reasons why the GOLD-N-RING Control Switch makes it possible to match machine tool mechanical ruggedness with equally durable electrical efficiency.



1 **MAIN BLOCK** is unit-molded to assure alignment and simplify assembly.

2 **HEAVY-DUTY SILVER-ALLOY CONTACT POINTS** for maximum electrical capacity and long life.

3 **HEAVY-DUTY TERMINAL SCREWS**, with 3/8" thread contact, prevent stripping during installation; permanently secure wires for continuous trouble-free service.

4 **BRASS INSERTS MOLDED IN THE BLOCK** permanently hold stationary contacts. They also provide more thread support for the No. 8-32 terminal screws that are equipped with captive flat and lock type washers.

For complete details, send for Bulletin ECS-56. Better yet, ask for a representative to bring a switch for your examination.

ELECTRICAL MANUFACTURING DIVISION

National Acme

THE NATIONAL ACME COMPANY • 188 EAST 131ST STREET • CLEVELAND 8, OHIO

Circle 421 on page 19

How Alcoa Aluminum Fasteners make good windows even better

MEETS AWMA STANDARDS!

You can meet the highest standards of quality and the specifications of the AWMA (Aluminum Window Manufacturers Association) for prime windows of aluminum when you assemble with Alcoa® Aluminum Fasteners. Perfect color match and protection against both galvanic and atmospheric corrosion make for lasting good looks . . . consumer satisfaction. Complete stocks carried by your local Alcoa distributor fill every requirement. He is listed in the Yellow Pages of your telephone directory.

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Your Guide to the Best in Aluminum Value

THE ALCOA HOUR
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2244-H Alcoa Bldg., Pittsburgh 19, Pa.
Gen. emen: Please send complete specification data and samples of Alcoa Aluminum Fasteners.
Name_____
Title_____
Company_____
Address_____

Circle 422 on page 19

for conventional cable. This factor, combined with low weight—2½ lb per 100 ft roll of 50-conductor cable—makes the product applicable where weight and space are critical.

Remarkably low interconductor capacitance makes the new cable useful in high-frequency applications. Less than 5 mmf per sq ft between conductors is claimed, and less than 1 mmf with alternate conductors grounded is obtained.

Mechanical properties include tensile strength of 80 lb per in. of width, which is greater than that of soldered connections. Various strain relief fittings are available to take full advantage of tensile strength. Flex life has been tested with satisfactory result in applications requiring continuous flexing on radius of ¼-in.

Any number of conductors may be treated as a single wire. Insulation can be stripped rapidly by pair of opposing high-speed glass-fiber wheels, conductors brought together, dip soldered, and insulated with tape to form a splice.

Fourth Mechanisms Conference to Have Larger Program

Discussions Will Cover Many New Design Developments

CLEVELAND, O. — An extensive and varied program is planned for the Fourth Conference on Mechanisms. The Conference is co-sponsored by the School of Mechanical Engineering, Purdue University, and MACHINE DESIGN. It will be held on the Purdue Campus, West Lafayette, Ind., on October 14 and 15.

Topics included in the program of more than ten papers are: Mechanism design in Germany, design of a constant-load cam, double-crank linkages, dwell-linkages vs. cams, a high-speed indexing mechanism, cam-follower equivalent mechanisms, relationship of statics, kinematics, dynamics in mechanism design, application of complex numbers to kinematic analysis and synthesis, and impact forces in elastic collisions of rigid bodies.

The Conference is aimed at providing opportunity for exchange of information on mechanism design at all levels—from practical everyday situations to advanced concepts of analysis and synthesis.

Social highlights of the program are a banquet on October 14 and a luncheon on October 15.

Registration fee for the Conference is $25.00 which will include the social affairs and transactions. Rooms will be available at the Memorial Union on Purdue Campus and at hotels and motels in Lafayette. Registration, travel, and housing details will appear in the next issue of MACHINE DESIGN.

Transistor-Sized Spacistor Has Higher Frequency Range

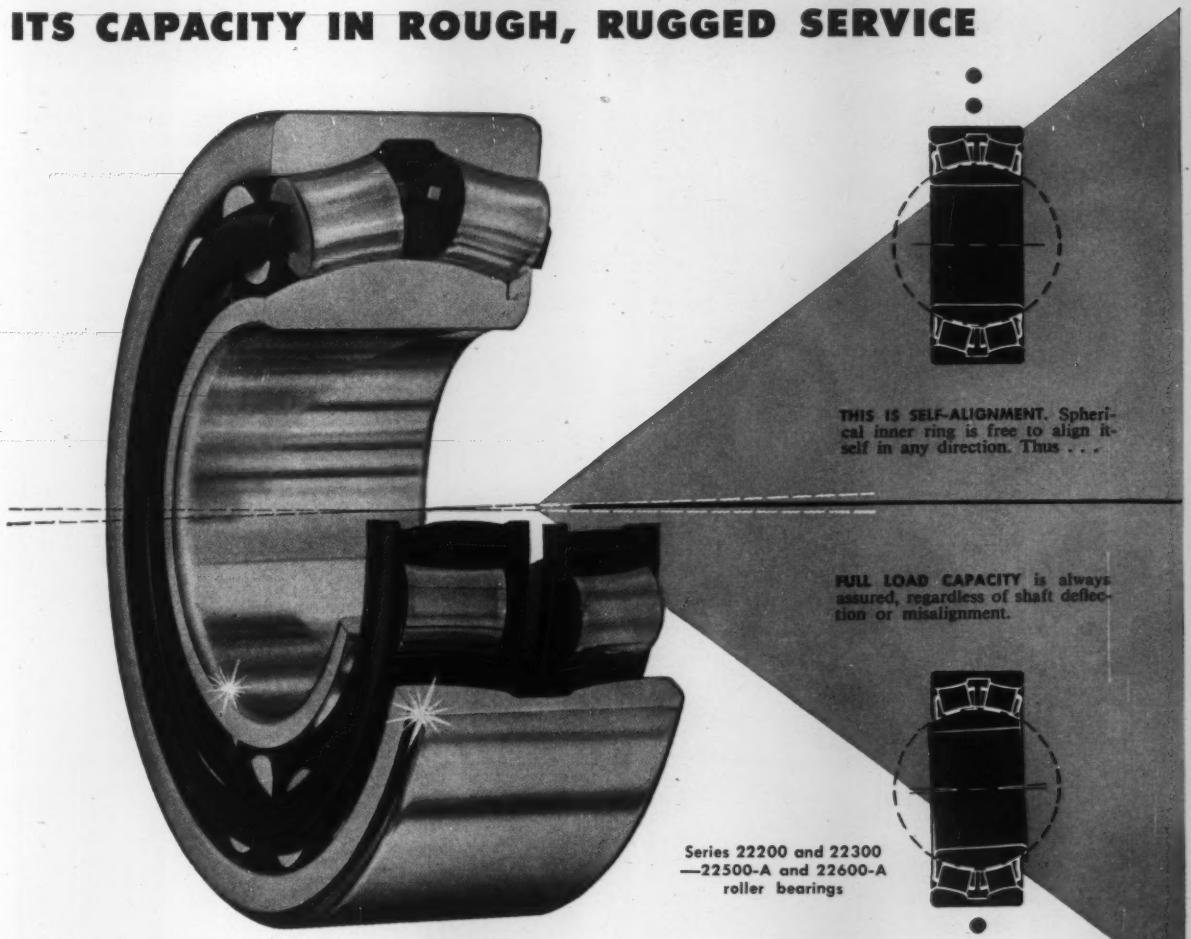
Fast-Acting Amplifier Also Beats the Heat

WALTHAM, MASS.—Spacistor, a new semiconductor amplifying device, appears to combine the best properties of vacuum tube and transistor, according to its inventors at Raytheon Mfg. Co.

Still in the research stage, the new device compares in size to a transistor, but is said to have two advantages: it will amplify frequencies ranging to 10,000 mc, 40 times higher than transistors; it

Experimental assembly comparing size of Spacistor with pin and boat-like transistor mount.

Self-aligning TO KEEP ITS CAPACITY IN ROUGH, RUGGED SERVICE


THIS IS SELF-ALIGNMENT. Spherical inner ring is free to align itself in any direction. Thus . . .
FULL LOAD CAPACITY is always assured, regardless of shaft deflection or misalignment.
Series 22200 and 22300 —22500-A and 22600-A roller bearings

Spherical LINK-BELT roller bearing compensates for shaft deflection, weaving of supports

MANY leading makers of tough duty equipment now design without bulky supports to prevent deflections. They're using this spherical Link-Belt roller bearing that *compensates for misalignment* . . . always keeps its full capacity for handling radial and thrust shock loads without "pinching."

In addition, it's factory-adjusted, easy to mount and available everywhere with internationally standardized boundary dimensions.

Link-Belt also makes industry's most complete line of ball and roller bearing blocks. They're all in Book 2550—yours for the asking at any of 40 Link-Belt offices. 14,443

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LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office, New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World.

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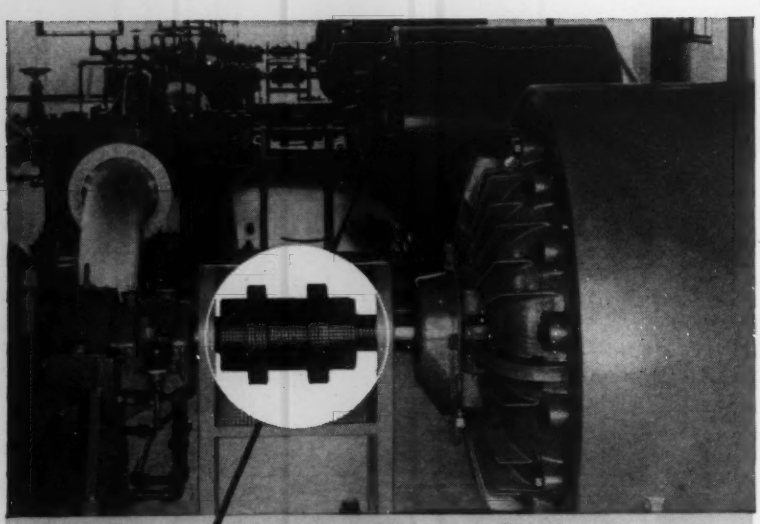
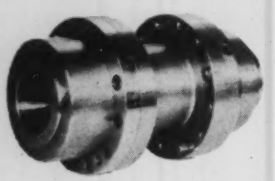


Waldron couplings in main line crude oil station

WALDRON

flexible couplings...



USED IN HUNDREDS OF DIFFERENT APPLICATIONS BUT ALWAYS FOR THE

same 3 reasons

1 STRENGTH — Hubs and cover sleeves for sizes 1¼A through 7A are machined from tough steel forgings. Hubs are keyed to the shafts. The two one-piece cover sleeves function as a single, rigid unit serving as a floating connecting link between the hubs. High strength of forgings makes possible a very compact coupling with low rotating inertia.

2 RELIABILITY — There are no flexible parts to bend or break and the coupling is dust, moisture, and oil tight. Patented Walflex seal is at the lowest possible diameter where centrifugal force is least. Clearance between teeth in hubs and sleeve is engineered so that an oil wedge always separates them, taking the wear.

3 SERVICE — Plenty of rough bore couplings, already assembled—on the shelf for *immediate* delivery. Finish bored standard couplings shipped to meet customers' schedules. We are geared up to give you realistic delivery on *any* type of couplings.

Ask for Catalog 57

JOHN WALDRON CORP.

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can be constructed of simpler materials that will withstand temperatures to 500 C, twice the maximum of transistors.

Higher frequency range of Spacistor is due to principle of operation that differs from transistor. A high electric field is produced between base and collector, limited only by breakdown voltage of semiconductor body. Spacistor uses the high field to accelerate electrons, greatly reducing their transit time. Transistors operate by diffusion of electrons through a base with limited field strength, which also limits frequency range.

Spacistors resemble transistors in other qualities, however. They operate on a fraction of vacuum tube power, have no filament or heat generating quality and can be tightly packed in minute assemblies.

Meetings

AND EXPOSITIONS

Aug. 28-30—

American Institute of Electrical Engineers. Pacific General Meeting to be held in Pasco, Wash. Additional information can be obtained from AIEE headquarters, 33 W. 39th St., New York 18, N.Y.

Sept. 4-6—

American Institute of Electrical Engineers. Magnetic Amplifiers Conference to be held at the Penn-Sheraton Hotel, Pittsburgh. Further information is available from institute headquarters, 33 W. 39th St., New York 18, N.Y.

Sept. 9-11—

American Institute of Electrical Engineers. Petroleum conference to be held at the Penn-Sheraton Hotel, Philadelphia. Further information can be obtained from AIEE headquarters, 33 W. 39th St., New York 18, N.Y.

Sept. 9-12—

Society of Automotive Engineers Inc. Tractor Meeting and Production Forum to be held at Hotel Schroeder, Milwaukee. Additional

information is available from society headquarters, 485 Lexington Ave., New York 17, N.Y.

Sept. 9-13—

Instrument Society of America. 12th Annual Instrument-Automation Conference and Exhibit to be held in the Public Auditorium, Cleveland. Further information can be obtained from Herbert S. Kindler, Director of Technical Programs, ISA, 313 Sixth Ave., Pittsburgh 22, Pa.

Sept. 17-20—

American Die Casting Institute. Annual Meeting to be held at the Edgewater Beach Hotel, Chicago. Additional information is available from institute headquarters, 366 Madison Ave., New York 17, N.Y.

Sept. 23-25—

American Society of Mechanical Engineers. Fall meeting to be held at Hotel Statler, Hartford, Conn. Further information is available from ASME headquarters, 29 W. 39th St., New York 18, N.Y.

Sept. 23-25—

Standards Engineers Society. Sixth Annual Meeting to be held at Hotel Commodore, New York. Further information can be obtained from G. H. Kitchen, Bell Telephone Laboratories Inc., Room 1B-118, Murray Hill, N.J.

Sept. 23-26—

Association of Iron and Steel Engineers. Annual convention to be held at the Penn-Sheraton Hotel, Pittsburgh. Further information is available from association headquarters, 1010 Empire Bldg., Pittsburgh 22, Pa.

Sept. 24-25—

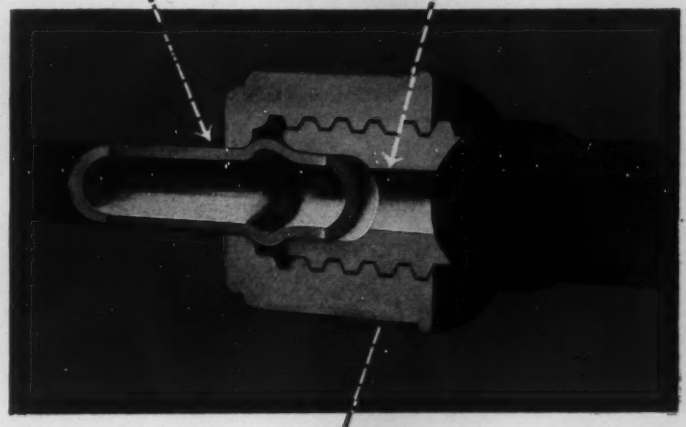
Sixth Annual Industrial Electronics Symposium to be held at the Morrison Hotel, Chicago. Sponsors are the Institute of Radio Engineers and the American Institute of Electrical Engineers. Further information can be obtained from H. L. Garbarino, Armour Institute of Technology, 10 W. 35th St., Chicago 16, Ill.

Oct. 1-5—

Society of Automotive Engineers

no solvent! no clamp!

no reduction in I D.!



This tube fitting is especially designed for flexible tubing...

At last—a tube fitting designed for plastic and rubber tubing. It's simple . . . fast . . . versatile. Requires no solvent, no clamp, no threading. And the new Danco tube fitting assures a union as strong as the tube itself.

If you have a tubing application in mind where you think this new tube fitting design can help, write today outlining your requirements. A free sample is available for your study.

DANIELSON MANUFACTURING COMPANY DANIELSON, CONNECTICUT
A SUBSIDIARY OF NICHOLSON FILE CO.

GENTLEMEN: Please send

☐ Free descriptive specification sheet

☐ Your representative to supply free sample

NAME.....

TITLE.....

COMPANY.....

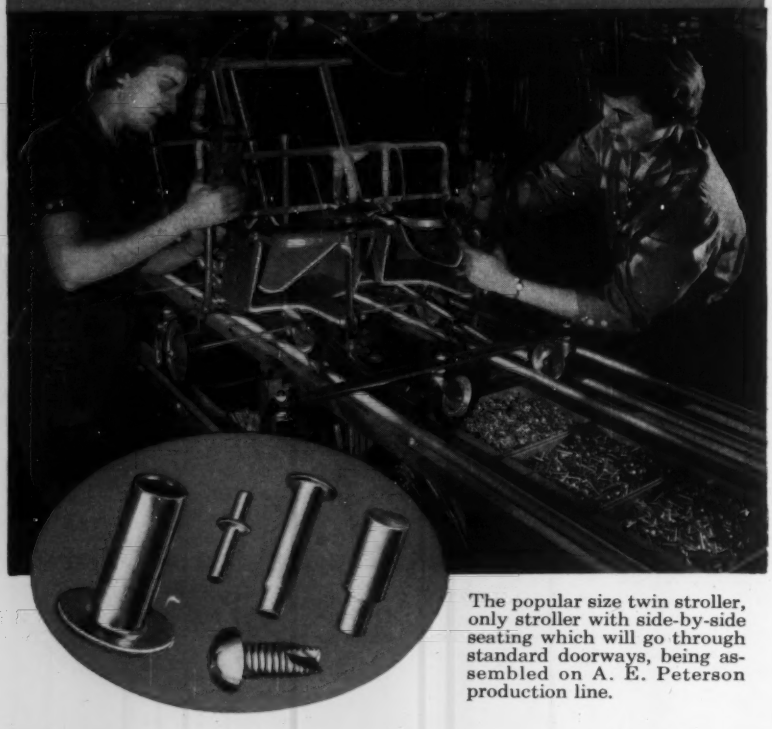
ADDRESS.....

YOUR APPLICATION IN PLASTIC OR RUBBER TUBING?.....

.....

Circle 425 on page 19

Foldability of Peterson Folda Products Depends Upon Quality Townsend Fasteners



The popular size twin stroller, only stroller with side-by-side seating which will go through standard doorways, being assembled on A. E. Peterson production line.

The extensive line of Folda products produced by A. E. Peterson Manufacturing Company, Glendale, California is designed for baby's safety and comfort—for mother's ease of handling. For instance, she has a choice of ten types and models of strollers.

In designing these unique folding walkers, strollers, chairs, swings, seats and steps, Peterson engineers also had quick, secure, efficient production line assembly in mind. That's why they chose Townsend Company special cold-formed parts, tubular rivets and tapping screws to do the fastening job.

Townsend special parts are used to attach the front wheels, casters and axles. Townsend standard and special tubular rivets are used at all pivot points—the important feature which permits folding for easy storage and handling of their products. Townsend tapping screws are used to attach arm rests and other non-removable parts.

Peterson officials give credit to dimensionally perfect Townsend parts for the permanent fastening they accomplish which has done much to establish their reputation for quality.

In your assembly operations why not take advantage of Townsend's experience in designing and manufacturing special and standard fasteners for a multitude of uses in all industry. To learn more about how to increase fastening efficiency, write for Bulletin TL-96a to Townsend Company, P.O. Box 237E, New Brighton, Pa.

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News Roundup

Inc. Aeronautic Meeting, Aircraft Production Forum and Aircraft Engineering Display to be held at the Ambassador Hotel, Los Angeles. Further information is available from SAE headquarters, 485 Lexington Ave., New York 17, N.Y.

Oct. 7-9—

American Society of Lubrication Engineers — American Society of Mechanical Engineers Joint Lubrication Conference to be held at the Royal York Hotel, Toronto. Further information can be obtained from ASLE headquarters, 84 E. Randolph St., Chicago 1, Ill.

Oct. 7-9—

National Electronics Conference. Annual meeting and show to be held at the Sherman Hotel, Chicago. Further information can be obtained from American Institute of Electrical Engineers, 33 W. 39th St., New York 18, N. Y.

Oct. 7-11—

American Institute of Electrical Engineers. Fall General Meeting to be held at the Morrison Hotel, Chicago. Additional information is available from AIEE headquarters, 33 W. 39th St., New York 18, N. Y.

Oct. 9-11—

Gray Iron Founders' Society Inc. Annual Meeting to be held at the Drake Hotel, Chicago. Further information can be obtained from society headquarters, National City—E. Sixth Bldg., Cleveland 14, O.

Oct. 9-11—

Fourth Annual Symposium of High Vacuum Technology to be held at Hotel Somerset, Boston. Sponsor is the Committee on Vacuum Techniques, P. O. Box 1282, Boston 9, Mass.

Oct. 14-15—

Fourth Conference on Mechanisms to be held at Purdue University, West Lafayette, Ind. Sponsors are the Purdue School of Mechanical Engineering and MACHINE DESIGN. Additional information can be obtained from the Editor, MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

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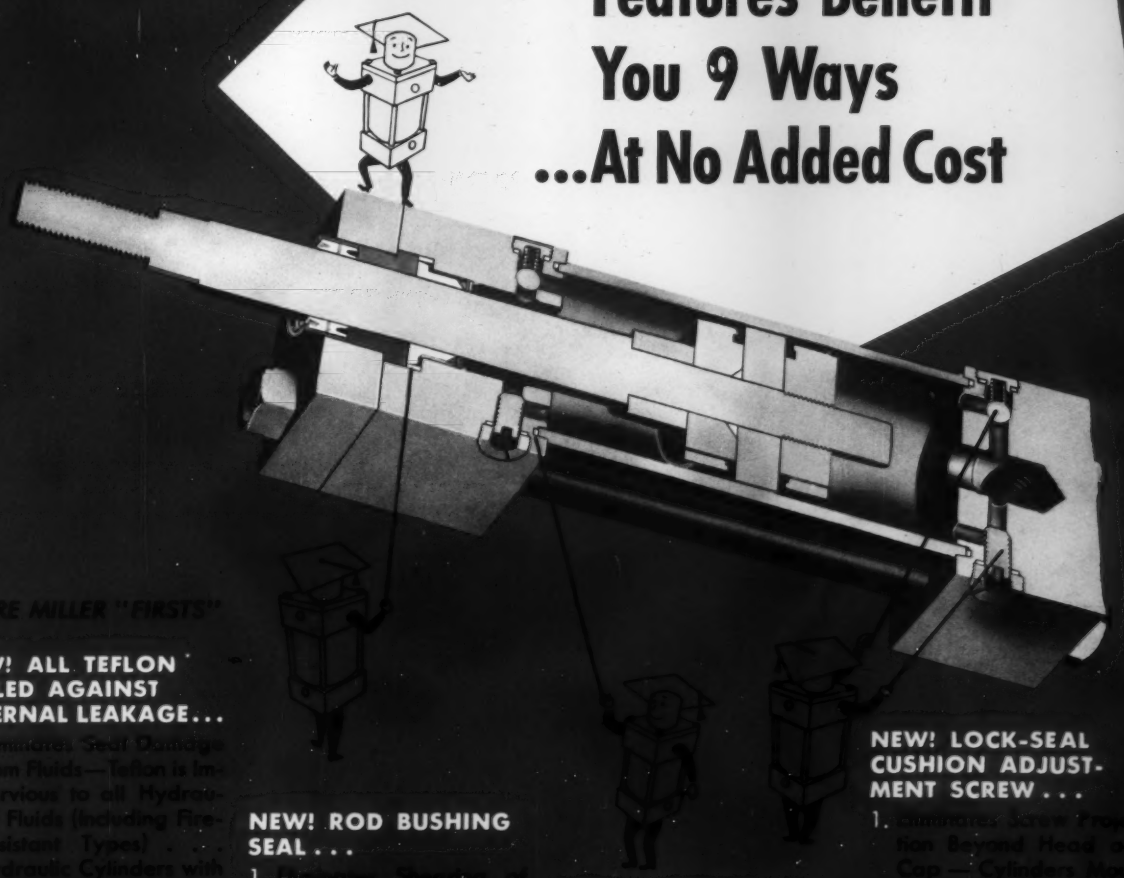
Circle 427 on page 19→

4 New Hydraulic Cylinder Features Benefit You 9 Ways ...At No Added Cost



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NEW! ALL TEFLON* SEALED AGAINST EXTERNAL LEAKAGE...

1. Eliminates Seal Damage from Fluids—Teflon is Impervious to all Hydraulic Fluids (including Fire-Resistant Types) . . . Hydraulic Cylinders with Teflon Piston Cups Slightly Higher.
2. Eliminates Seal Damage from High Temperatures—Teflon Sealed Cylinders Operate At —100° F. to 500° F.

NEW! ROD BUSHING SEAL . . .

1. Eliminates Shearing of "O" Ring in Re-Assembly
2. Eliminates Extrusion of "O" Ring at Extreme Pressures.

NEW! SHEF SEAL AT TUBING ENDS . . .

1. Eliminates Shearing of "O" Ring in Re-Assembly
2. Eliminates Extrusion of "O" Ring at ANY Pressure—Teflon Sealing Ring is Backed Up by Zero Clearance Metal Shoulder.

NEW! LOCK-SEAL CUSHION ADJUSTMENT SCREW . . .

1. Eliminates Screw Projection Beyond Head and Cap — Cylinders Mount on Any Side.
2. Eliminates Manual Sealing and Locking After Flow Adjustment—Teflon Seal is Self Regulating and Self Locking.
3. Eliminates Accessibility Problems—Cushion Screw Interchangeable with Ball Check Position—Adjustable Through Small Wrench Hole Drilled in Interfering Machinery.

*du Pont trademark for its tetrafluoroethylene resin

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Turn Page For Cross Section Of SHEF SEAL

S SHEAR PROOF
H HEAT PROOF
E EXTRUSION PROOF
F FLUID PROOF
SEAL

Teflon Pressure Energized

Hydraulic Cylinder Tubing End Seal

PAT. APPLIED FOR

OTHER MILLER QUALITY FEATURES

- Case-Hardened Chrome Plated Piston Rod
- Rust Resistant Surfaces
- Teflon Oil and Dirt Wipers
- Interchangeable Square Design

FLUID POWER DIVISION

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HYDRAULIC CYLINDERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS • BOOSTERS

Miller®

Announces a New Space and Price Saving Hydraulic Cylinder Line

SAVE UP TO 76% OF COST

Heavy Duty Model LH—Same Size As Ordinary Gasket Type Square Design Low Pressure Cylinders

BORE	NORMAL RATINGS	NON-SHOCK INTERMITTENT RATINGS	YOU SAVE THIS % IN PRICE OVER STANDARD 2000-3000 PSI CYLINDERS
1½"	1500 PSI	2500 PSI	27%
2	1500	2500	27%
2½	1000	1500	28%
3¼	1500	2500	32%
4	1000	1500	35%
5	800	1200	37%
6	800	1200	43%
8	500	800	50%
10	500	800	71%
12	500	800	76%
14	500	800	*Not Available in 2000-3000 PSI*

MORE MILLER "FIRSTS"

Miller®

Announces 50% More Power Per Cylinder Dollar

with Extra Heavy Duty

3000-5000 PSI MODEL H

HYDRAULIC CYLINDERS

Same Price and Mounting Dimensions as Miller 2000-3000 PSI Hydraulic Cylinders.

BOTH LINES MADE POSSIBLE BY SHEF SEAL

Miller FLUID POWER DIVISION

OTHER MILLER QUALITY FEATURES

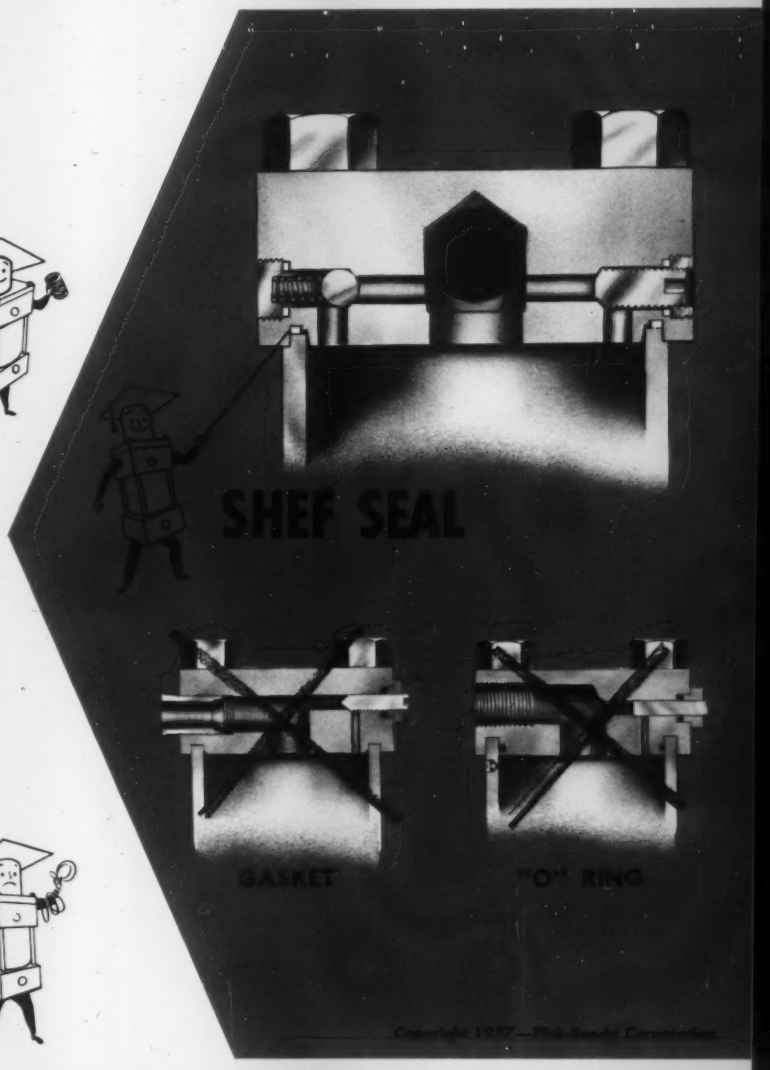
- All Teflon Sealed Against External Leakage—Teflon Cups Extra
- Case-Hardened Chrome Plated Piston Rod
- Shear Proof Rod Bushing Seal
- Ball Check Interchangeable with Self Sealing and Locking Cushion Adjustment
- Rust Resistant Surfaces
- Teflon Oil and Dirt Wipers

S SHEAR PROOF
H HEAT PROOF
E EXTRUSION PROOF
F FLUID PROOF
SEAL
Teflon Pressure Energized
Hydraulic Cylinder Tubing End Seal
PAT. APPLIED FOR

SHEF SEAL Obsoletes All Other Hydraulic Cylinder End Seals . . . *at no added cost*

HAS EVERY ADVANTAGE

1. Pressure Energized—Sealing Effectiveness Increased with Pressure.
2. Zero Metal-To-Metal Clearance at all Pressures Gives You Perfect Seal Backup. Sealing Ring Cannot Extrude.
3. Simplified Servicing. No "Blind" Assembly. Sealing Ring Cannot Shear.
4. Teflon* Sealing Ring Withstands All Hydraulic Fluids at Temperatures from —100° F. to 500° F.
5. Head and Cap Axial Movement Does Not Destroy Sealing.
6. Allows Air Bleed In Head and Cap for Remote or Automatic Bleeding.
7. One Sealing Ring Cross Section Dimension For All Cylinder Sizes—Supplied On Convenient Spools.
8. Zero Metal Backup Clearance Eliminates Dangerous Leaks and Spurts of Fluid Due To Seal Failure.



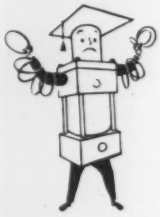
NONE OF THESE DISADVANTAGES

GASKET CONSTRUCTION

1. Unpredictable Results—Leaks and Blows Even at Low Pressures.
2. Outlawed by J.I.C. Eight Years Ago.
3. Seal Failure Causes Dangerous Leaks and Spurts of Fluid. Creates Unnecessary Fire and Safety Hazard.

"O" RING CONSTRUCTION

1. High Pressures and Shock Loads Expand Tubing—Increase Clearance and Cause Extrusion.
2. Blind Assembly Can Shear Sealing Ring—Difficult Servicing.
3. Seal Failure Causes Dangerous Leaks and Spurts of Fluid. Creates Unnecessary Fire and Safety Hazard.
4. Requires Large Inventory of "O" Rings
   —For Servicing Variety of Cylinder Bores.
   —For Special Synthetic Rubber Compounds To Meet Ever Changing Fluid and Temperature Needs.



*du Pont trademark for its tetrafluoroethylene resin.

When you buy Miller ... You buy extra years of worry-free Cylinder performance ...at competitive prices

SHEF SEAL—*Another Miller "First"*

S SHEAR PROOF
H HEAT PROOF
E EXTRUSION PROOF
F FLUID PROOF
SEAL
Teflon Pressure Energized
Hydraulic Cylinder Tubing End Seal
PAT. APPLIED FOR

OTHER MILLER QUALITY FEATURES

- All Teflon Sealed Against External Leakage—Teflon Cups Extra
- Case-Hardened Chrome Plated Piston Rod
- Shear Proof Rod Bushing Seal
- Ball Check Interchangeable with Self Sealing and Locking Cushion Adjustment
- Rust Resistant Surfaces
- Teflon Oil and Dirt Wipers

Miller FLUID POWER DIVISION

Turn Page For More About MILLER

AIR AND HYDRAULIC CYLINDERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS • BOOSTERS

All Teflon Sealed —Perfect Sealing for Hydraulic Cylinders

HAS EVERY ADVANTAGE...

Teflon—As Static and Dynamic Seals

1. Impervious to Every Hydraulic Fluid Including Fire-Resistant Types.
2. Seals Perfectly in Cylinders at Temperatures from —100° F. to 500° F.
3. Can Be Molded Into Shapes That Have Zero Leakage—Hold Pressure Indefinitely.
4. With Proper Design of External Seal Cavities, Teflon Can Be Included *Without* Increasing Prices. Miller Provides Teflon for all External Seals at Prices Competitive with Ordinary Cylinders. Leather Internal Piston Cups are Standard (Teflon Cups Extra).

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Printed in U.S.A.

•du Pont trademark for its tetrafluoroethylene resin.

When you buy Miller
You buy extra years
of worry-free
Cylinder performance
...at competitive prices

NONE OF THESE DISADVANTAGES

Synthetic Rubber— As Static and Dynamic Seals

1. Unsatisfactory Except When Used With A Limited Range of Hydraulic Fluids.
2. Even Uncontrollable Changes in Fluid Additives Often Destroy Seal.
3. Specific Compounds Needed for Compatibility with Specific Fluids Normally Used Today.
4. Normal Temperature Range Limited to 0° F. to 130° F. Slightly Reduced Life When Operated at 130° F. to 150° F. Greatly Reduced Life at 150° F. to 250° F.
5. External Leakage Causes Fire and Safety Hazards When Temperature or Fluid Destroys Seals.
6. "U" Type Seals Without Mechanical Retainer at Mid-Section Frequently "Roll" and Lose All Sealing Ability.

Resin Impregnated Leather— As Dynamic Seals Only

1. Is Compatible with Many—But Not All—Hydraulic Fluids and Additives Including a few Fire-Resistant Types.
2. Normal Temperature Range Limited to —60° F. to 130° F. Slightly Reduced Life When Operated at 130° F. to 150° F. Substantially Reduced Life at 150° F. to 250° F.
3. External Leakage Causes Fire and Safety Hazards When Temperature or Fluid Destroys Seals.
   Miller Uses Leather Piston Cup Seals for Internal Sealing... Standard Price (Teflon Cups Extra).

Piston Rings— As Dynamic Internal Seals

1. Most Piston Rings Allow Some Leakage.
2. Allow "Slip" or "Drift" of Piston Due To Leakage—Unsatisfactory for Many Applications.
3. Allow Varying Feed Rates Due To Leakage Because Of Viscosity Change During Startup—Unsatisfactory for Most Multiple and Automated Operations.
4. Allow Some Pressure Loss.
5. Chips and Dirt Enter Space Between Piston and Tube Causing Scoring —Especially During Startup.

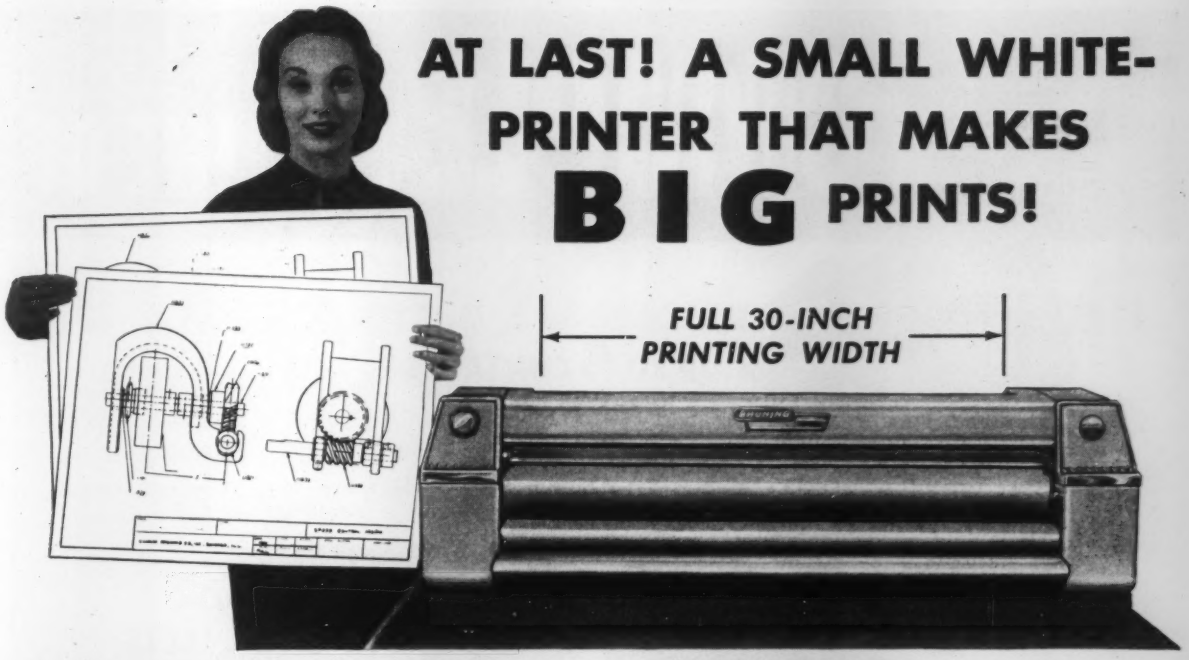
All Teflon Sealed—*Another Miller "First"*

Miller FLUID POWER DIVISION
FLUID-READY CORPORATION
2006 N. Hawthorne Ave., Melrose Park, Ill.

AIR AND HYDRAULIC CYLINDERS • ACCUMULATORS
COUNTERBALANCE CYLINDERS • BOOSTERS

OTHER MILLER QUALITY FEATURES

- All Teflon Sealed Against External Leakage—Teflon Cups Extra
- Case-Hardened Chrome Plated Piston Rod
- Shear Proof Rod Bushing Seal
- Ball Check Interchangeable with Self Sealing and Locking Cushion Adjustment
- Rust Resistant Surfaces
- Teflon Oil and Dirt Wipers



AT LAST! A SMALL WHITE-PRINTER THAT MAKES BIG PRINTS!

BRUNING NEW! Copyflex Model 300!

Brings "Inside" Reproduction within the Means of the Smallest Engineering Firm or Department!
Now, with your low-cost, versatile Model 300, you can make high quality prints when you want them—rapidly, privately, and in any quantity. You can exercise complete control over valuable originals at all times.

Provides Large Companies an Economical Way to Supplement Main Reproduction Centers!
With its compact size, big printing width, and low cost, the Model 300 is an ideal helper for your big reproduction machine. Strategically located throughout your company, Model 300s can bring new speed, convenience, and efficiency to your reproduction operations.

Here it is! The compact, low-cost reproduction machine that offers all the versatility and big printing width of a large, expensive whiteprinter!

Just think—you can make sharp, black-on-white prints in seconds of a drawing or tracing up to 30 inches wide by any length. And anyone can operate the Model 300 after only brief instruction. One fingertip control turns the machine on or off, and regulates its speed. Exposure and development are automatically synchronized.

The new Copyflex Model 300 is ideal for drafting rooms and offices because it can operate anywhere without annoyance to personnel in the vicinity. It is clean, quiet, and odorless. No exhaust venting, plumbing, or accessory equipment required. It needs only a connection with a 115-volt AC outlet for operation.

If you're pressed by the boom in production for more and more engineering prints, the all-new Copyflex Model 300 is your answer! Its low initial cost combined with outstanding economy and convenience of operation and maintenance make it your soundest, low-cost investment of the year. Mail coupon today! You'll be glad you did!

BRUNING Copyflex

Best Process! Best Machines! Best Selection of Materials!

Offices in 37 Cities of the U.S. and Canada

CHARLES BRUNING COMPANY, INC., CHICAGO

In Canada: Charles Bruning Co. (Canada) Ltd., 105 Church St., Toronto 1, Ont.

CHARLES BRUNING CO., Dept. 83-K
4700 Montrose Ave., Chicago 41, Ill.

Please send me information on the all-new Copyflex Model 300.

Name_____ Title_____

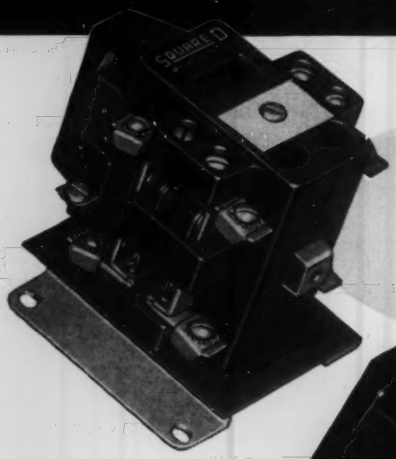
Company_____

Address_____

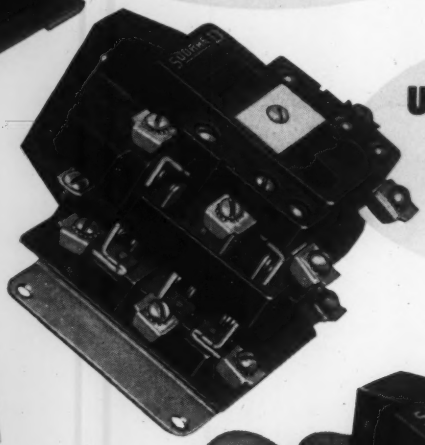
City_____ County_____ State_____

Circle 428 on page 19

A COMPLETE LINE OF



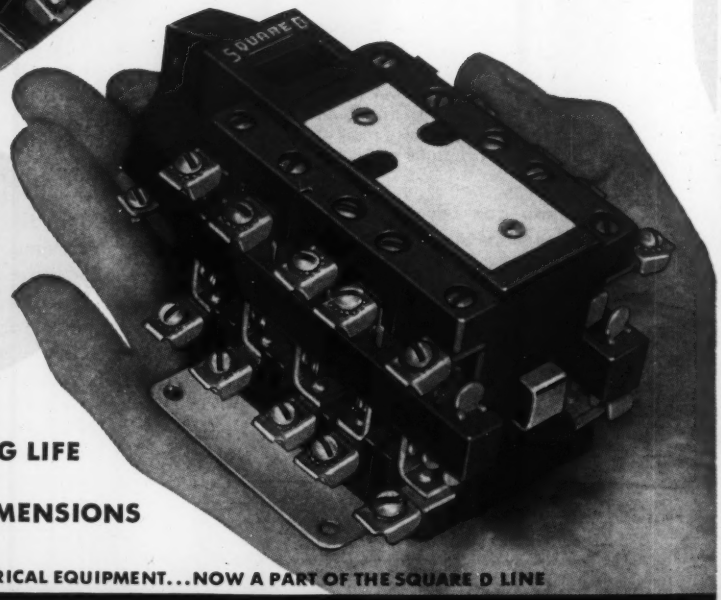
UP TO 4 CONTACTS
2 Normally Open
2 Normally Closed
Measures only
3-5/16″ high x 2-5/8″ wide!



UP TO 6 CONTACTS
4 Normally Open
2 Normally Closed
Measures only
3-11/16″ high x 2-13/16″ wide!

NEW!

UP TO 10 CONTACTS
Either 6 Normally Open and
4 Normally Closed or
8 Normally Open and
2 Normally Closed
Measures only
5″ high x 3″ wide!



600 VOLTS 10 AMPERES LONG LIFE
ALL THREE SIZES HAVE
IDENTICAL MOUNTING HOLE DIMENSIONS

EC&M HEAVY INDUSTRY ELECTRICAL EQUIPMENT...NOW A PART OF THE SQUARE D LINE

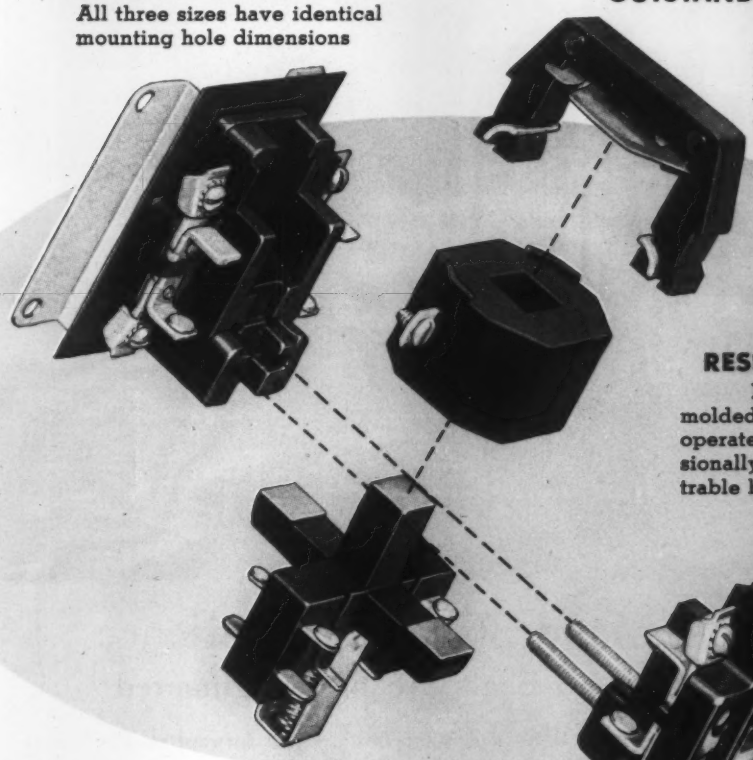
SQUARE D COMPANY

SPACE-SAVING RELAYS

Take Them Apart in 20 seconds...from the Front!
Not One Bit of Tear-Down Space Needed!

MOUNTING SIMPLIFIED
All three sizes have identical mounting hole dimensions

OUTSTANDING PERFORMANCE
Balanced construction reduces wear on single moving part...results in long life and safeguards against down-time



RESISTS DAMAGE
Plastic impregnated molded coil is unbreakable, operates cooler, is dimensionally stable and impenetrable by water and oil

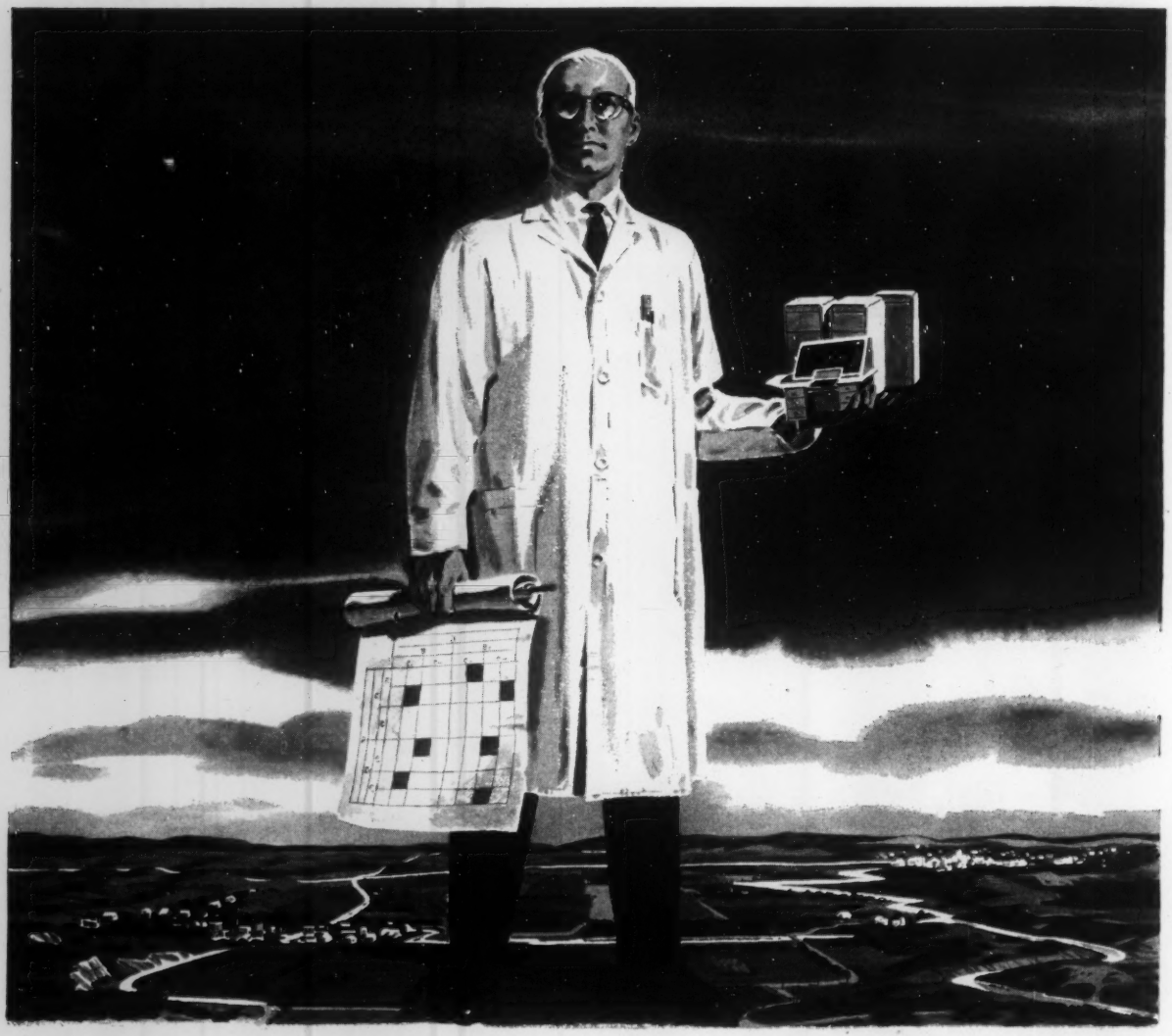
20-SECOND DISASSEMBLY
Simply loosen two screws and the entire device is disassembled for normal maintenance

PACKAGED PARTS KITS
make normal maintenance easier than ever. Any way you look at it, these new relays are tops. Small in size—long on features and performance

for the Complete Story, write for Bulletin 8501-D
Address Square D Company, 4041 North Richards Street, Milwaukee 12, Wisconsin

Everybody's Ahead with Square D!

Circle 429 on page 19



Latin Square, Univac and 36 years experience

all three help assure National Seals are best engineered

Univac you know, experience you know; the Latin Square? An ancient, half-forgotten solver of problems having many variables. Today, National Seal engineers use it to reduce exploratory engineering time as much as 75%.

Old, new, time-tested and visionary—National Seal engineers embrace every approach that can help keep National Seals the best engineered in America. Results have been good. Syntech®, the milestone in synthetic rubber seals and Micro-Torc®, major forward step in leather seals, are but two examples.

National Seal's advanced engineering, in plant or field, is ready now to help you solve sealing problems. This help is yours for a telephone call.

VITAL: Whatever seals you buy, save trouble and expense later on by specifying them "on the board." For safety, have specifications checked by a National Seal engineer.

NATIONAL SEAL Division, Federal-Mogul-Bower Bearings, Inc.

General Offices: Redwood City, California; Plants: Van Wert, Ohio, Redwood City and Downey, California

36th Year

National Field Engineers At Your Service: Chicago, Ill., Room 462, McCormick Building, HArrison 7-5163 • Cleveland, Ohio, 210 Heights Rockefeller Bldg., YEllowstone 2-2720 Dallas, Texas, 2520 West Mockingbird Lane, FLeetwood 2-7541 • Detroit, Mich., 13836 Puritan Avenue, VErmont 6-1909 Downey (Los Angeles Co.), Calif., 11634 Patton Rd., TOpaz 2-8163 • Indianapolis, Indiana, 2802 North Delaware St., WAlnut 3-1535 Milwaukee, Wis., 647 West Virginia St., BRoadway 1-3234 • Newark, N. J., 1180 Raymond Blvd., MItchell 2-7586

4228

Circle 430 on page 19

TO PRODUCE QUALITY
SOCKET SCREWS THE H-K WAY—

OUR LABORATORY CONDUCTS EXHAUSTIVE PHYSICAL AND CHEMICAL TESTS WITH THE MOST MODERN EQUIPMENT

Conventional testing isn't enough . . . we subject H-K screws to rigid tests in our TEN-TOR *machine to determine resistance to both tensile and torque stresses. Because we test the finished screws and not just material, you can be sure every H-K Socket Screw will stand up under the toughest application.*

For the finest in socket screw products . . . for unmatched SAME-DAY SERVICE—the name to remember is Holo-Krome. Write for free catalog and technical information.

HOLO-KROME SOCKET SCREWS

THE HOLO-KROME SCREW CORPORATION • HARTFORD 10, CONN.

SOLD ONLY THROUGH AUTHORIZED H-K DISTRIBUTORS

Circle 431 on page 19

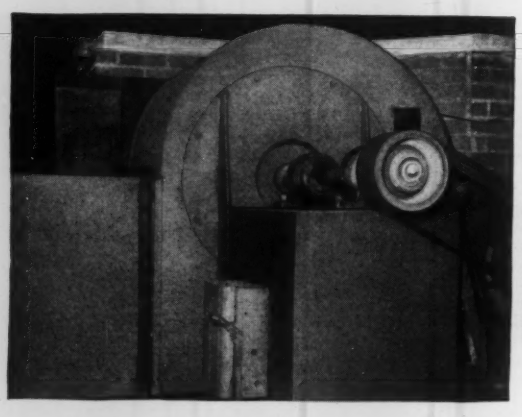
We would like to say that we are very well pleased with the "Buffalo" Fans we are using on our tunnel kiln installations. The "NV" Propeller Fan which Buffalo Forge designed for us for our drier operation is undoubtedly the best fan of this type we have used.

— from a leading manufacturer who builds "Buffalo" Fans into his products (name on request)

...and here's why

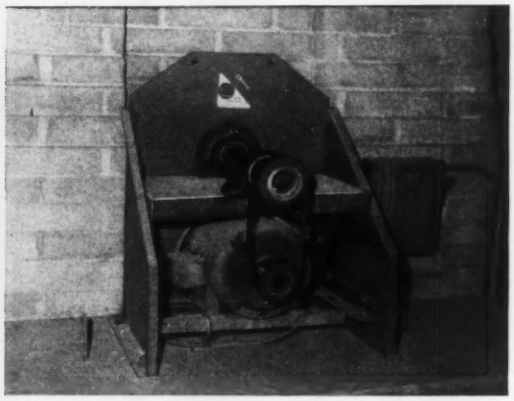
"BUFFALO" FANS WILL SUIT YOU, TOO

- HIGH EFFICIENCY
- QUIET OPERATION
- STABLE PERFORMANCE
- DESIGN FLEXIBILITY
- COMPLETE SELECTION
- "Q" FACTOR* RELIABILITY
- "SPECIAL" FANS ENGINEERED-TO-ORDER



At left — "Buffalo" Type "BL" Fan moving 14,000 cfm waste heated air from Tunnel Car Kiln to dryer.

At right — One of 3 "Buffalo" Dryer Recirculating Fans on Car Kiln. "Buffalo" "NV" Propeller Wheel mounted on end of shaft projected thru kiln wall.



INQUIRIES CONCERNING YOUR AIR HANDLING PROBLEM ARE INVITED.

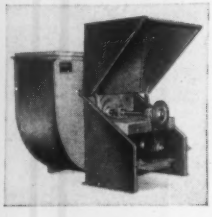
**The "Q" Factor — the built-in Quality which provides trouble-free satisfaction and long life.*

BUFFALO FORGE COMPANY

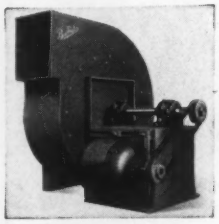
BUFFALO, N. Y.

Canadian Blower & Forge Co., Ltd., Kitchener, Ont.

"Buffalo" Volume Fans for blowing, exhausting jobs up to 10" s.p., have moisture-proof cast iron housings, dust-proof ball bearings.



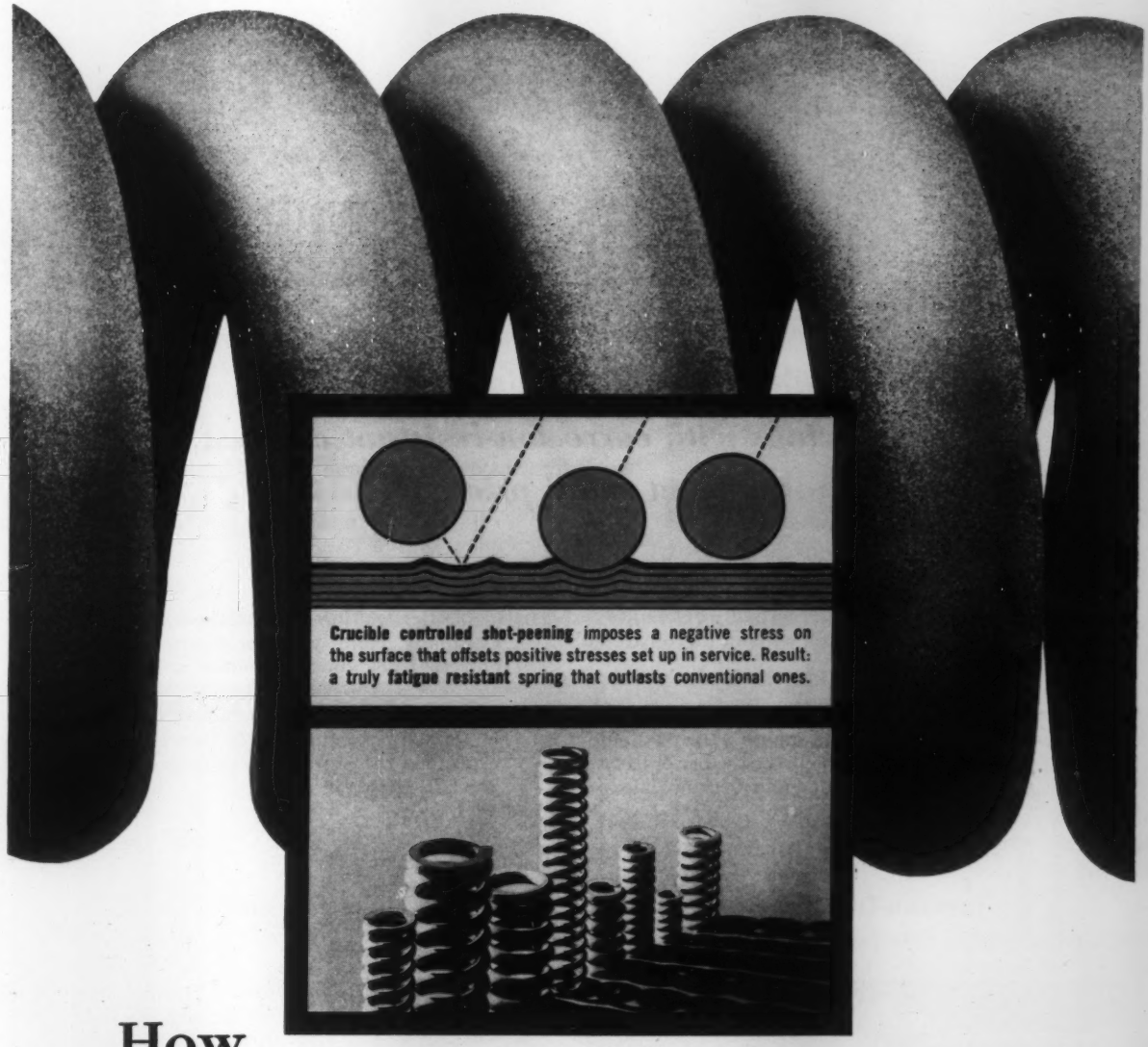
"Buffalo" Belted Vent Sets are light-weight "packages" for small-system ventilation. Highly efficient and quiet. Write for Bulletins.



"Buffalo" All-Welded Industrial Exhausters handle any materials suitable for a pneumatic system. Heavy steel plate wheels and housings.

VENTILATING AIR CLEANING AIR TEMPERING INDUCED DRAFT EXHAUSTING FORCED DRAFT COOLING HEATING PRESSURE BLOWING

Circle 432 on page 19


Crucible controlled shot-peening imposes a negative stress on the surface that offsets positive stresses set up in service. Result: a truly fatigue resistant spring that outlasts conventional ones.

How CRUCIBLE FATIGUE RESISTANT SPRINGS are made stronger to last longer...

First, every Crucible *fatigue resistant* industrial spring is shot-peened. It's the best way to insure high fatigue resistance under rugged operating conditions. And it makes the spring stronger by eliminating stress concentration points that could lead to spring failure.

But, most important, Crucible gives you full measure of the two factors upon which good springs depend: good spring design, and fine steel.

In addition to Crucible's staff of proven spring designers and spring makers is Crucible's years of experience in fine steel making—from ore to finished spring. When you have a spring application, let an experienced Crucible spring specialist suggest the best spring for it. And write for a free copy of the "Handbook of Coil Spring Design". *Spring Division, Crucible Steel Company of America, McCandless Avenue, Pittsburgh 1, Pa.*

CRUCIBLE spring division

Crucible Steel Company of America

Designing with BAKELITE Plastics

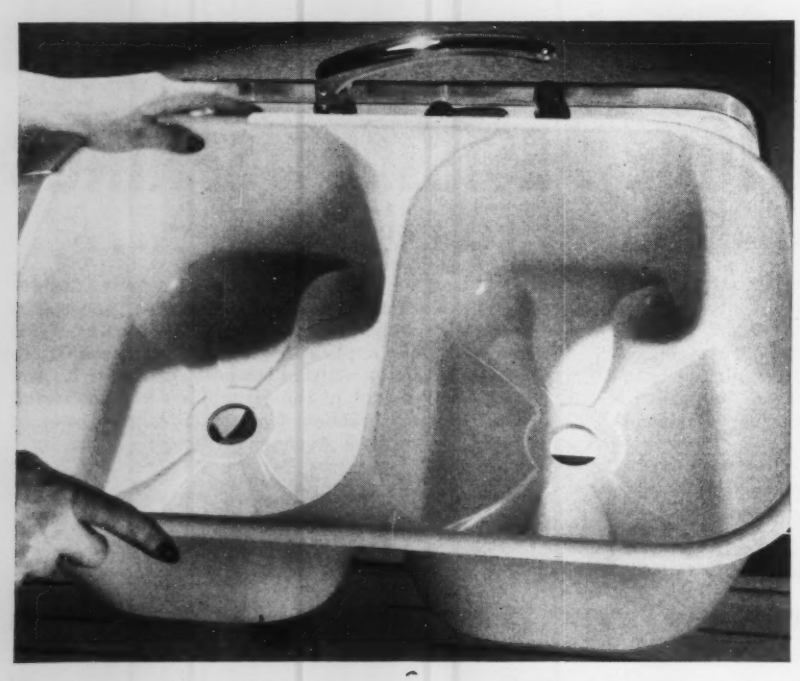
- ***Plastic converts the kitchen sink***
- ***Savings with corrosion-resistant exhaust ducts***
- ***Giant tools at small prices***

New materials create new design ideas . . . tougher coatings, parts made faster, built-in chemical resistance, or weight reduced without loss of strength . . .

Perhaps you have an idea that's been waiting for a material to make it work.

These are reasons for examining the possibilities in plastics, the newest, liveliest category of basic materials. Plastics make news in design almost daily, because they do so much so well. Your best source of plastics and information about them is Bakelite Company. Here, you can choose from styrenes, polyethylenes, vinyls, phenolics, polyesters, epoxies, silicones and impact styrenes—the largest variety in the plastics field. And in addition, you can draw on Bakelite Company experience and technical assistance for aid in applying these materials to your design problems.

1 Vacuum-formed from impact styrene—two sinks for one



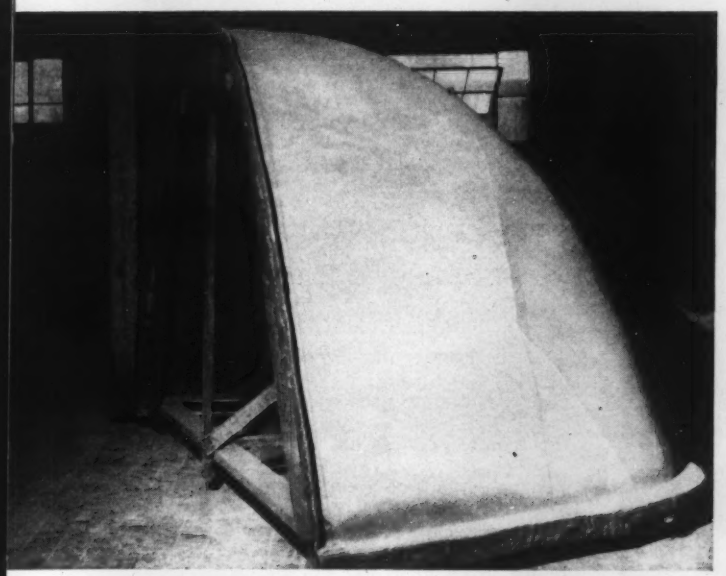
This design idea is the "Dual-Sink-Tray" insert for kitchen sinks that gives the housewife a double sink in an instant. The inventor makes it of BAKELITE Brand Impact Styrene TMD-2155, extruded by Campco, because this material has all the performance advantages he requires—in addition to a high Izod impact strength (3.6 ft. lb./in. of notch, ¼ in. thick), it offers a choice of colors, resistance to household cleaners and light weight. Its resilience prevents dishes from chipping or cracking.

This product is fabricated by a simple, economical, vacuum-forming process that affords deep draws and intricate design on a mass production basis. If you are interested in BAKELITE High-Impact Styrene and the vacuum-forming operation, write Dept. ZA-103.

2 Exit corrosive atmospheres . . . through corrosion-resistant plastic ducts

Laminations of BAKELITE Brand Resins for reinforced plastics and glass fibers are extensively used for large-sized structures. They are light in weight, strong, and resistant to attack by many chemicals and corrosive fumes. Since they need no protective coating, their maintenance is low. The example shown here is part of an exhaust system in a plant for pickling brass sheets. Air laden with sulphuric acid fumes passes through hoods and ducts to a scrubber that removes the fumes and expels them through a stack—all elements in the system being reinforced plastic made of these resins and glass fiber. The scrubber, weighing 500 lbs., would weigh about 2000 lbs. if made of metal, an important factor in reducing roof stress. For more information, write Dept. ZB-103.

3 Large-scale tools made with long-lived, dimensionally stable epoxy



Jigs, checking fixtures, and similar tools, large and small, have many advantages when made from glass cloth and BAKELITE Brand Epoxy Resins. The tools shown here have already been in service for three years, forming reinforced plastic swimming pool sections. They are among the world's largest plastic tools. In another material, the cost of tools this size, with comparable durability, accuracy, and dimensional stability, would be prohibitive.

In fabrication, epoxy resins are handled as liquids, so that they can be poured into place after being mixed with their liquid hardener. They cure overnight with almost no alteration in dimensions, and after curing, can be machined or patched if design changes are called for. Finished tools are extremely hard, and resistant to chipping and cracking. Another interesting application for this epoxy resin-glass cloth construction is its use for patching dented automobile fenders, since the epoxy has excellent adhesion to metal. For more information, write Dept. ZC-103.

There's more to design with in **BAKELITE** BRAND **PLASTICS**

POLYETHYLENES • SILICONES • POLYESTERS • EPOXIES
PHENOLICS • IMPACT STYRENES • STYRENES • VINYLS

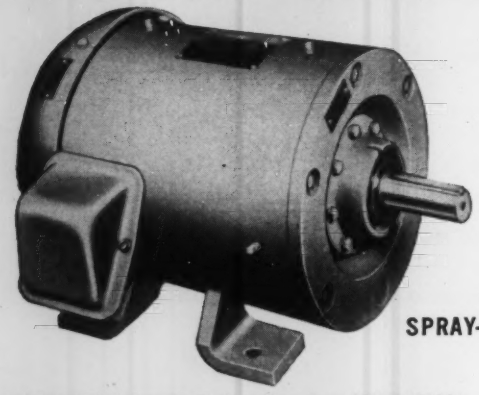
UNION CARBIDE

BAKELITE COMPANY, *Division of Union Carbide Corporation,* 30 East 42nd Street, New York 17, N. Y.

The terms BAKELITE, UNION CARBIDE and the Trefoil Symbol are registered trade-marks of UCC.

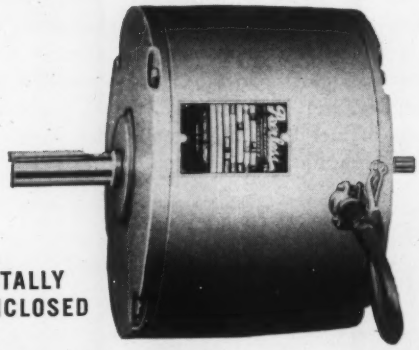
Circle 434 on page 19

ONLY ONE MOTOR IS RIGHT FOR YOUR APPLICATION...



SPRAY-TIGHT

Fan cooled; 7½ HP; Navy; Hi-shock to Navy Spec. MIL-M-17060A.

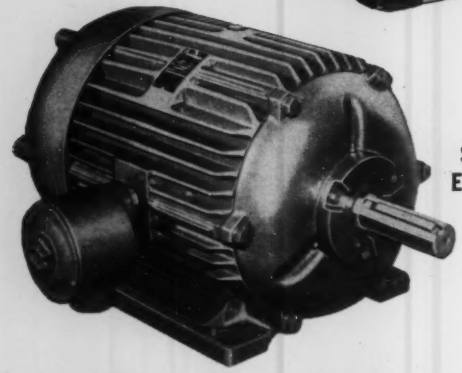


TOTALLY ENCLOSED

Blower and Drive Motor; 4 HP; air drawn over motor.

SPECIAL CONSTRUCTION

Motor to fit customer's application design.



STANDARD EXPLOSION-PROOF MOTOR

1 to 30 HP; also with NEMA C face and NEMA D flange.

● One thing's certain—just one motor is right for your application. Design engineers turn to Peerless more often than ever today because Peerless is equipped to produce the motors that power their machines best. There's no need to fit the machine to the motor. Peerless has hundreds of motor designs—many of them created specifically to meet OEM problems. Give your next motor problem to the Peerless Representative near you or write directly to the factory. We'll work with you to develop the one motor that meets your needs best.

ELECTRIC MOTOR DIVISION

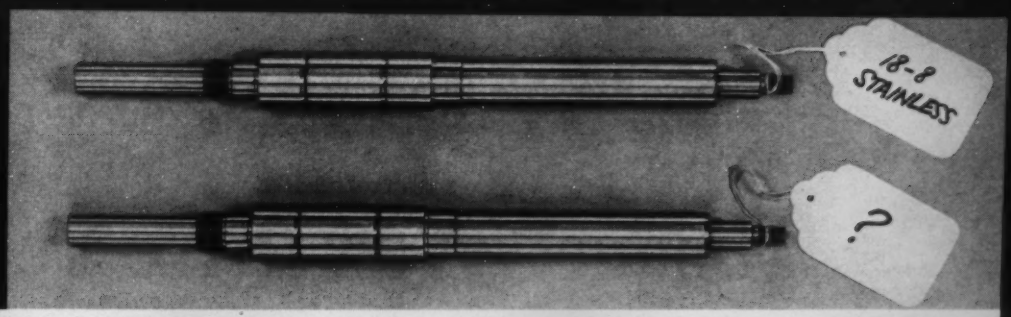
THE *Peerless-Electric*® COMPANY

FANS · BLOWERS · MOTORS · ELECTRONIC EQUIPMENT

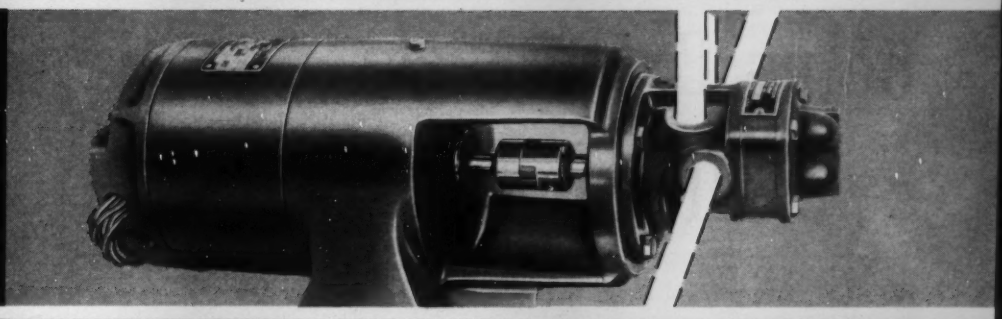
1520 W. MARKET ST. · WARREN, OHIO

Circle 435 on page 19

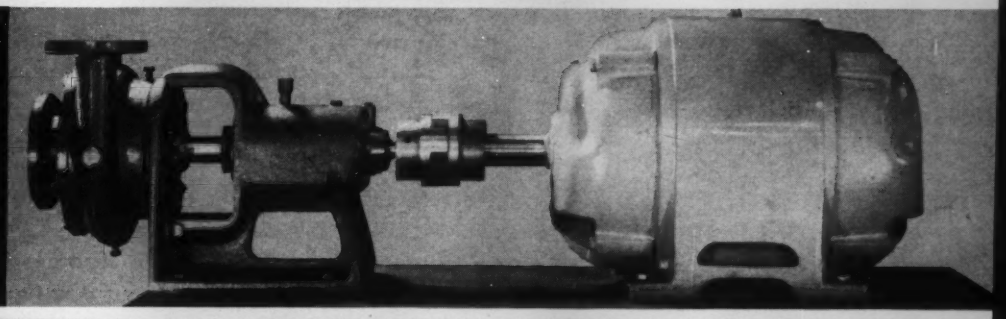
1. What's more "stainless" than "stainless steel"?



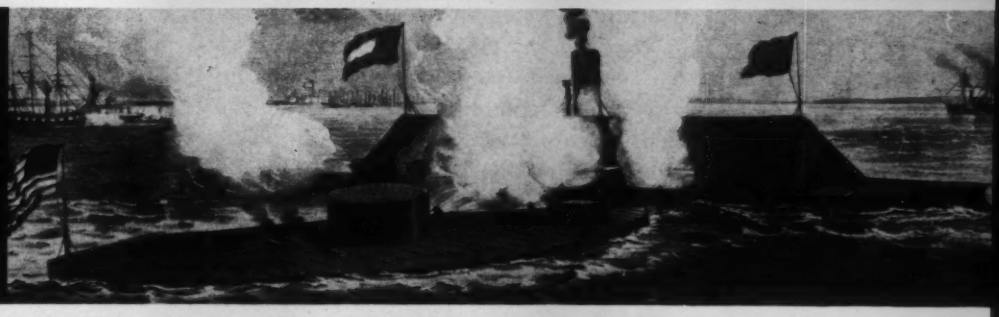
2. What's the newest in rotary pump hook-ups?



3. It comes in 70,480 combinations. Can you name the line?



4. Whose pumps would you have found in the Merrimac? Monitor?



WHAT'S YOUR P.Q.? (PUMP QUOTIENT)

1. *Answer:* Worthite*. Worthite is Worthington's super stainless steel for chemical pumps. Containing over 50% more alloy than 18-8 stainless, Worthite gives one third greater corrosion coverage for just a few cents more per pound. Bulletin W-350-B4 has complete details about Worthite.

2. Dual suction and discharge openings are the newest idea in rotary pumps. Available on the new Worthington Monobloc Rotary, they allow a choice of 28 different piping arrangements. In addition to simplified hook-ups, the new Worthington Monobloc Rotaries have many new convenience features such as standardized flange and shaft diameters to eliminate alignment. Flexible coupling allows rapid pump replacement without disturbing motor. For more information write for Bulletin W-484-B1.

3. The pump you see is just one of the 70,480 combinations available in Worthington SESC line. An abbreviation for "Standard End Suction Centrifugal," SESC pumps are the most versatile, most flexible you can buy. They give you a choice of 5 types of liquid ends, 4 materials of construction, 2 shaft sealing methods and 5 different drives. Write for Bulletin W-300-B4.

4. Even way back in 1862, engineers appreciated the value of pumps built by Worthington. Both the Merrimac *and* the Monitor were equipped with Worthington pumps. Today as then, whenever men must move liquid, they turn to the company with a reputation for reliability. Worthington Corporation, Harrison, New Jersey. PC. 7.14

*A high nickel, high-chromium, corrosion resistant alloy steel. Trademark Reg. U. S. Pat. Off.

WORTHINGTON

Circle 436 on page 19

Unique V-Belt Drive Design helps Brunswick Pinsetter perform all functions automatically

Resulting from years of design engineering, the new Brunswick Fully Automatic Pinsetter does an essentially human job with speed and effortless precision.

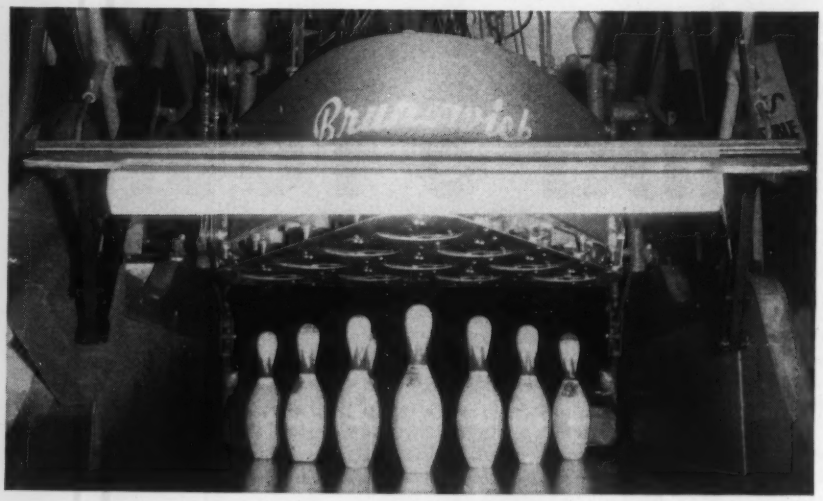
The Pinsetter has three main functions: (1) return the ball to the bowler, (2) sweep fallen pins from the alley and convey them to the pin deck so they can be set for another frame, and (3) determine, automatically, whether the first or second ball has been thrown and whether the bowler made a strike or left pins standing with his first ball.

One of the impressive features of this design is the wide use of V-Belt drives in the pin and ball delivery systems. In this extremely compact and simplified answer to a highly complex design problem, 13 V-Belts are driven from a single heavy-duty motor. *The designers say they favor V-Belts because they are a noiseless and dependable method of power transmission.*

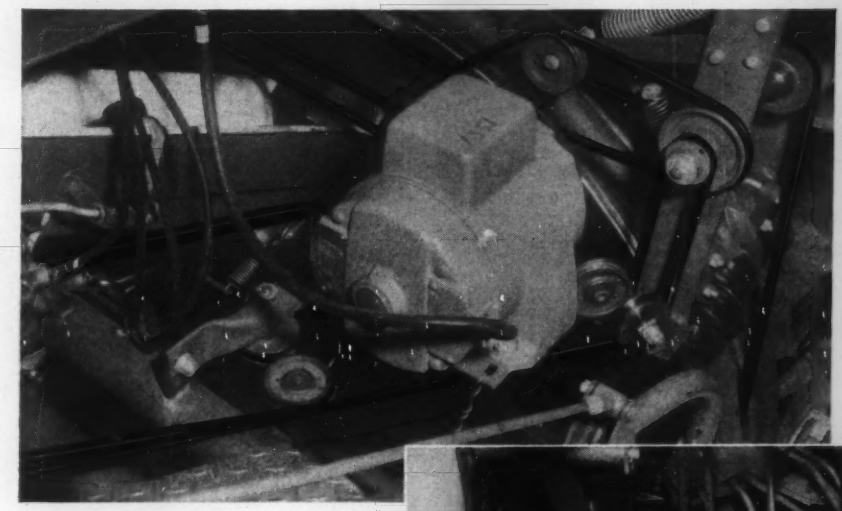
At the same time, the desire for compactness made highly unusual demands upon the V-Belts. At various locations they were required to exhibit no slip . . . high slip . . . low stretch . . . and extreme flexibility. They should be non-dusting . . . supply power from both sides of the belt . . . *and last through a long, trouble-free life of efficient service.*

Dayton is proud to have their V-Belts chosen for use on the rugged Brunswick Automatic Pinsetter.

News of the latest advances in rubber technology and expert design assistance are available to you through Dayton V-Belt Design Engineer. Contact him the next time you have a power transmission problem by writing The Dayton Rubber Company, Industrial OEM Division, Dayton 1, Ohio.

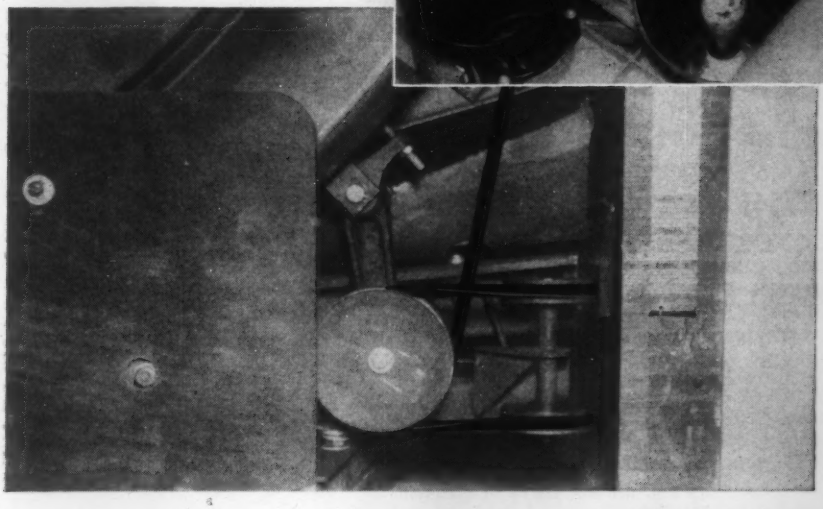


Poised in front of the pin deck is the rake which moves down and rearward to sweep fallen pins into the pit. Barely seen inside each pin chute are a pair of mechanical fingers—operated by a toggle linkage—which grip the standing pins while the alley is cleared in preparation for respotting for a spare.



This single heavy-duty motor furnishes power for 13 V-Belt drives which operate the pin and ball elevators, the pin conveyor, and the turret indexing mechanism. Note the unusually difficult service conditions imposed by the two-pulley backside idler located below and to the left of the motor.

The Pin conveyor carries each pin from the elevator to the pin turret partially visible at the top part of the photo. One V-Belt delivers power to the turret indexing clutch while the Cog-Belt* rotates the turret to receive each pin. When the turret is full it drops all ten pins into the deck below.



V-Belts transmit power to oscillate the shaker pit through this mule drive near the base of the Pinsetter. Movement of the pit bed urges the ball and pins rearward into the paths of the ball and the pin elevators.

If you haven't received your copy of Dayton's authoritative Handbook of V-Belt Drive Design and Selection, write for it now. Just give us your name, title, and the address of your firm.

Industrial Sales Engineers in Atlanta, Chicago, Cleveland, Dallas, Dayton, Moline, New York, San Francisco and St. Louis.

Dayton Rubber

WORLD'S LARGEST MANUFACTURER OF V-BELTS

THE DAYTON RUBBER CO. INDUSTRIAL O.E.M. DIV., DAYTON 1, OHIO

*T. M.

© D. R. 1957

Circle 437 on page 19

No matter how you say it . . .

*TRANSLATION: CUTTING OIL

The performance and the brand are the same around the world

Other Outstanding Shell Industrial Lubricants

Shell Tellus Oil—for closed hydraulic systems

Shell Alvania Grease—multi-purpose industrial lubricant

Shell Turbo Oil—for utility, industrial & marine turbines

Shell Rimula Oil—for heavy-duty diesel engines

Shell Talona R Oil 40—anti-wear crankcase oil for diesel locomotives

Shell Dromus Oils, a quality line of soluble cutting oils, permit higher speeds and greater feeds while extending tool life. They have excellent wetting and cooling properties and are not sticky or greasy.

Dromus® Oils have the added advantage of being easy to mix in hot or cold, hard or soft water. They form emulsions which remain stable in practically any concentration required in the shop.

Today Dromus Oils are available to your customers abroad. You can be sure that they will enjoy the same efficient performance your domestic customers rely upon.

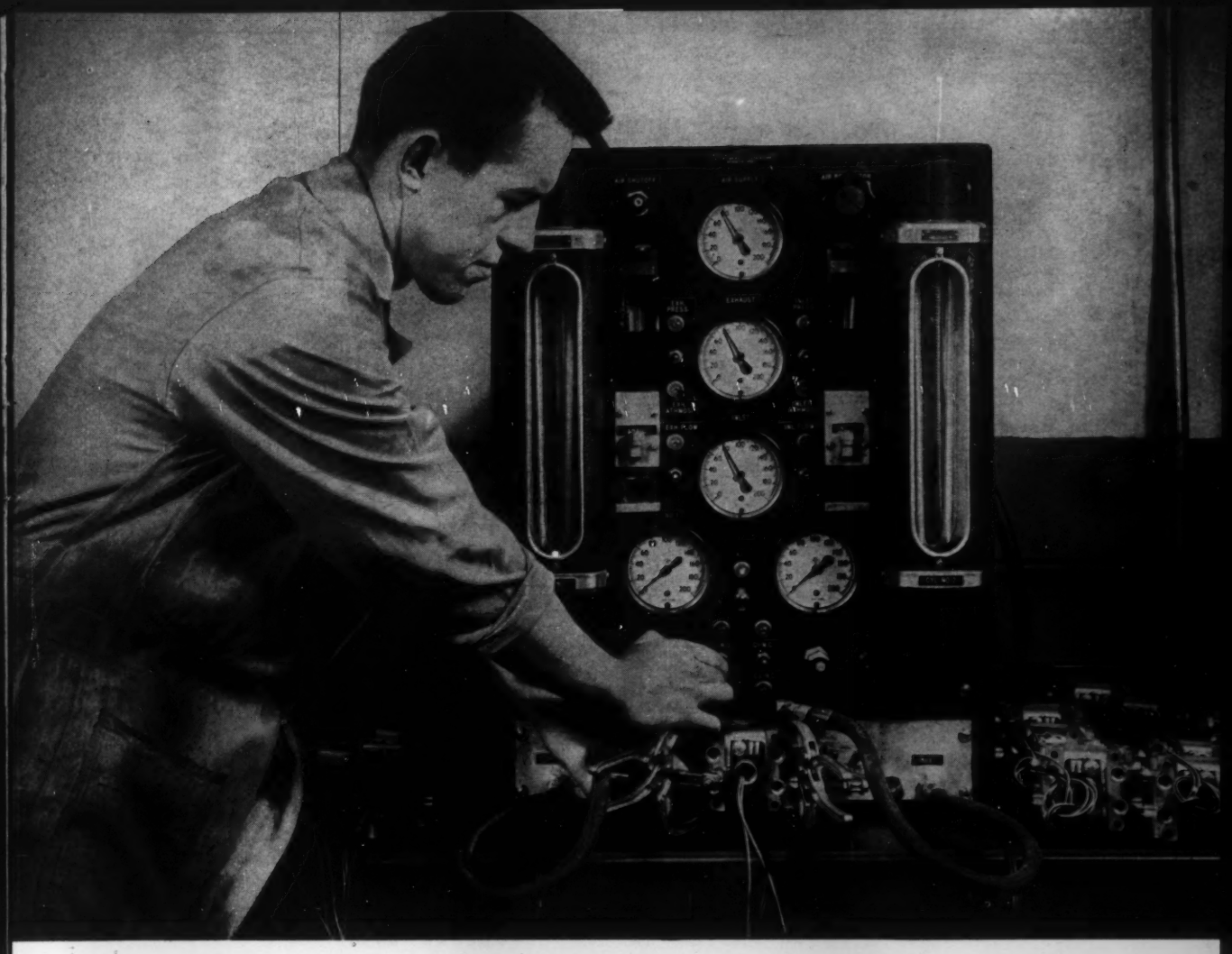
• • •

For more information, write Shell Oil Company, 50 West 50th Street, New York 20, N. Y., or 100 Bush Street, San Francisco 6, California.

SHELL DROMUS OILS

SHELL

Circle 438 on page 19



The 100% testing of all Skinner Solenoid Valves is your guarantee of consistent leakproof life

Every single Skinner Solenoid Valve receives 100% leakage inspection before shipment. Each one is tested under full pressure conditions at every point for both internal and external leakage. Modern, sensitive equipment like that shown above is used to quickly detect any defect.

In laboratory tests Skinner valves are regularly getting over 20 million cycles without leakage. And these remarkable results are constantly proving out in service.

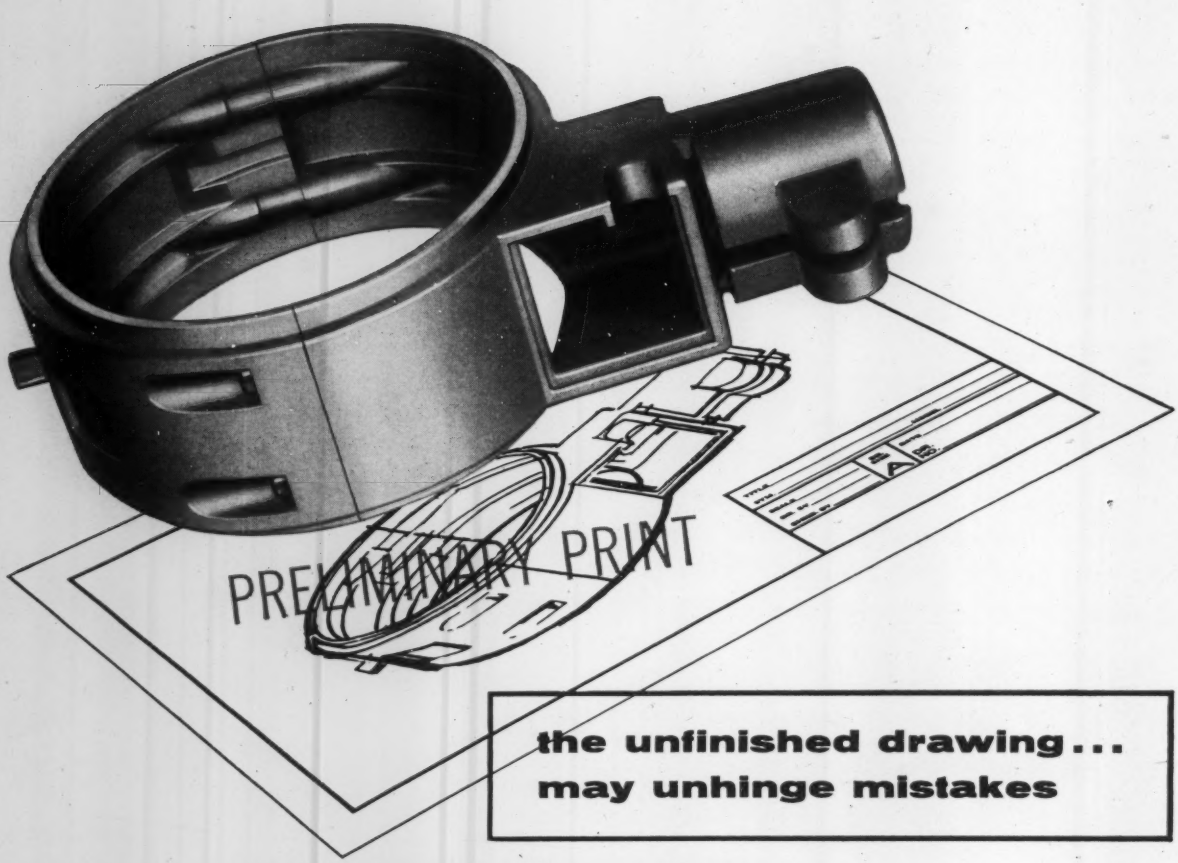
In vacuum service, for example—and in critical test equipment—standard Skinner valves are frequently specified because of their record for outstanding trouble-free performance.

So, if you are looking for solenoid valves with exceptionally long leakproof life, look to Skinner valves. For complete information on Skinner's line of 2-, 3- and 4-way valves, write us or contact a Skinner representative. Write Dept. 428.

Skinner Solenoid Valves are distributed nationally

Circle 439 on page 19

SKINNER ELECTRIC VALVE DIVISION
NEW BRITAIN CONNECTICUT
THE CREST OF QUALITY



the unfinished drawing...
may unhinge mistakes

with MADISON-KIPP zinc and aluminum die castings

The most successful product designers we know of, are those who send us their early sketches for review.

A die casting die represents the part drawing "turned inside out." Our practiced and practical die designers can do the turning mentally to expose any trouble spots in die making and die operation. Early design changes may promote substantial economies. They almost always advance time schedules.

It is standard procedure for our customers of long standing to send us their drawings as soon as there are enough lines to reveal the part design.

Please clip this ad as a reminder to contact us when you have die casting requirements.

kipp

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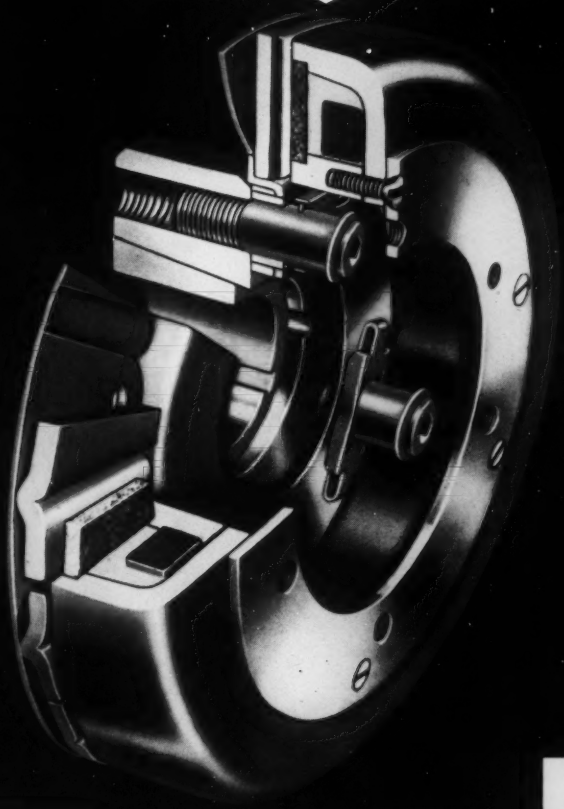
- Skilled in Die Casting Mechanics
- Experienced in Lubrication Engineering
- Originators of Really High Speed Air Tools

Circle 440 on page 19

Circle 441 on page 19→

THEY'RE NEW!



THEY CUT MAINTENANCE COSTS!

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FAST OPERATION • SELF ADJUSTING • EFFICIENT
SMOOTH, EASILY CONTROLLED ENGAGEMENT
WIDE RANGE OF SIZES AND CAPACITIES

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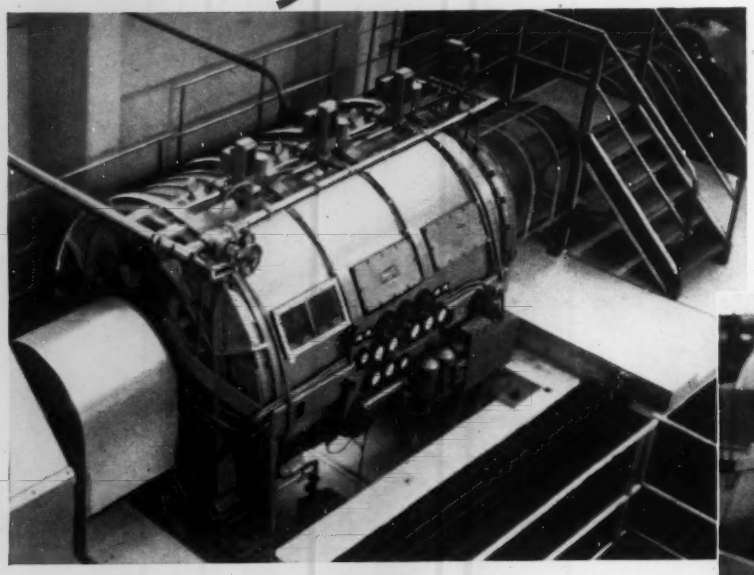
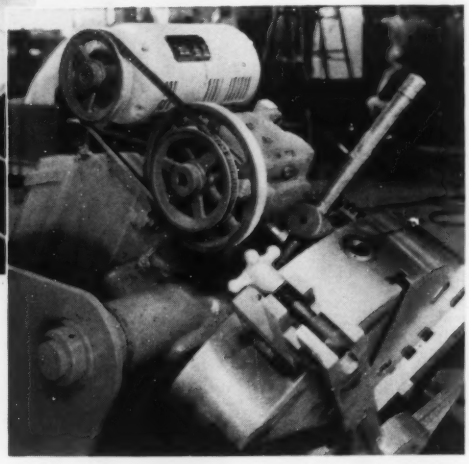


OR

¼ HORSEPOWER



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Write today for illustrated bulletins describing Dynamatic Eddy-Current Couplings and Drives—the modern method of speed control.

Need a big 20,000 horsepower drive? Or a compact, low-cost ¼ horsepower drive? For either requirement—or for any of the thousand-and-one applications between these extremes—Dynamatic Eddy-Current Drives, Couplings, and Brakes provide the ideal solution to difficult speed or torque control problems. Their efficiency and economy are being proven every day in every major industry—in both plant equipment and end product applications. Dynamatic equipment offers such important advantages as instantaneous response, infinitely adjustable speed control, wide speed range, quiet operation, low power loss, low maintenance costs, and adjustable speed from an AC power source.

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DYNAMATIC DIVISION
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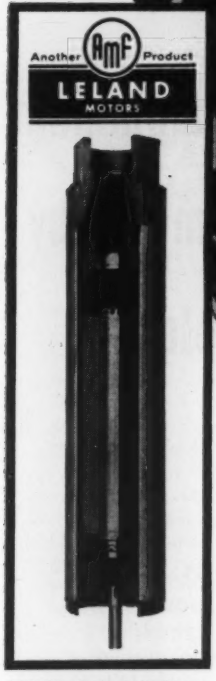
3307 FOURTEENTH AVENUE • KENOSHA, WISCONSIN

NOTE
LONG, SATISFACTORY PERFORMANCE OF REVERE COPPER AND BRASS PARTS IN THEIR MOTORS LED LELAND ELECTRIC COMPANY TO TAKE ITS ALUMINUM PROBLEMS TO REVERE
LESS MACHINING
Saves on Production Costs
LESS WEIGHT
Saves on Metal



CUTAWAY of the radically new submersible explosion-proof pump motor made by LELAND ELECTRIC COMPANY which can be installed right in the gasoline storage tank. In this pump motor the fluid passes between the stator core and the extruded shell while in the conventional submersible pump motor a double shell is used. Stator shell of the LELAND MOTOR is 13 9/16" long and 3 1/2" O.D. and is made from a hollow Revere Aluminum Extrusion.

REVERE HOLLOW ALUMINUM EXTRUSION USED IN REVOLUTIONARY SUBMERSIBLE PUMP MOTOR FOR LELAND ELECTRIC COMPANY

The original design of this stator shell called for a casting but when the design engineers considered the factors that would be encountered, and the symmetry of shape, it became apparent that an aluminum extrusion might have many advantages over a casting.

At this stage Revere T.A. (Technical Advisory) Service, which in the past had proved helpful, was called in for collaboration and the advantages of extrusions vs. castings were discussed. By using extrusions there would be no problem of porosity which is often present in castings. Substantial savings in weight would be made and the only machining would be to the ribs on the inside of the tube. No machining of the outside of the tube would be required, which would be necessary should a casting be used, while the smoother surface on the inside would improve flow characteristics—an important factor in this particular pump motor as the fluid being pumped passes between the stator core and the extruded shell. With the smooth surface of an extrusion, less horsepower would be used to pump a given volume of fluid. The result was the Revere Aluminum Extrusion you see above.

This is still another example of Revere supplying the right metal in the right form to do the best job with the greatest economy . . . be it aluminum, copper or any one of their alloys. Why not consult Revere when you design?

REVERE COPPER AND BRASS INCORPORATED

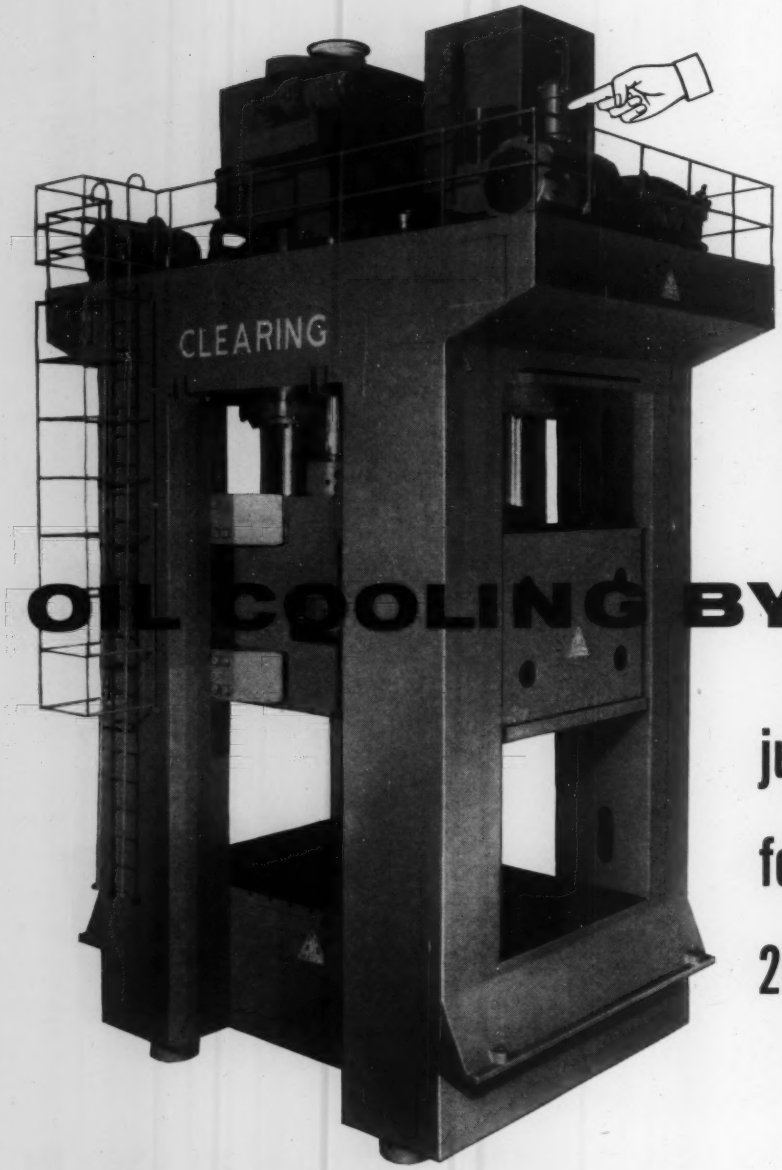
Founded by Paul Revere in 1801

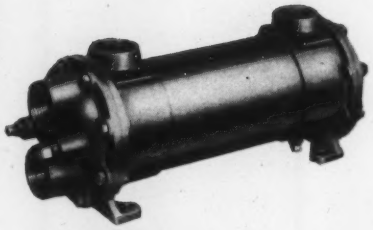
230 Park Avenue, New York 17, N. Y.

Mills: Baltimore, Md.; Brooklyn, N. Y.; Chicago, Clinton and Joliet, Ill.; Detroit, Mich.; Los Angeles and Riverside, Calif.; New Bedford, Mass.; Newport, Ark.; Rome, N. Y. Sales Offices in Principal Cities, Distributors Everywhere.

COPPER • BRASS • 18 01 • REVERE • ALUMINUM

Circle 442 on page 19





OIL COOLING BY ROSS

jumbo size aluminum forgings trimmed by 2000-ton colossus

Featuring a bed area of 16 feet by 8 feet, this towering 2000-ton Clearing Hydraulic Press trims massive aluminum forgings with steady speed and efficiency.

AN IMPORTANT FACTOR in assuring its peak performance is continuous cooling of oil in the hydraulic system. A Ross Type BCF Exchanger was factory-installed as an original component. Mounted on the crown of the press, it dissipates excessive heat, preventing breakdown of oil viscosity with consequent pump slippage and lost capacity.

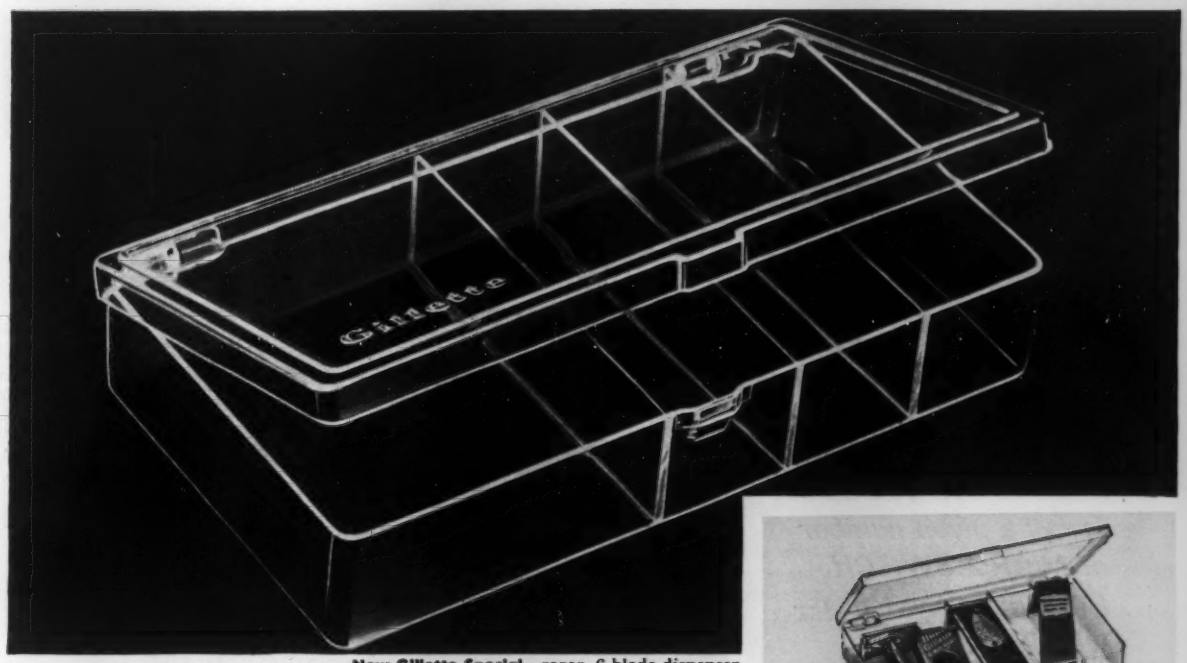
PREFERRED INDUSTRY-WIDE, Ross Exchangers are featured as built-in equipment on engines, lubrication systems, and hydraulic machines of every description to cool lube oil, jacket water and hydraulic fluid. Unrivalled for ruggedness and heat transfer efficiency, they're completely pre-engineered and fully standardized in a broad range of sizes to meet your specific needs.

For detailed information on Ross Type BCF Exchangers, request Bulletin 1.1K5. Ross Heat Exchanger Division of American-Standard, Buffalo 5, N.Y. In Canada: American-Standard Products (Canada) Limited, Toronto 5, Ont.

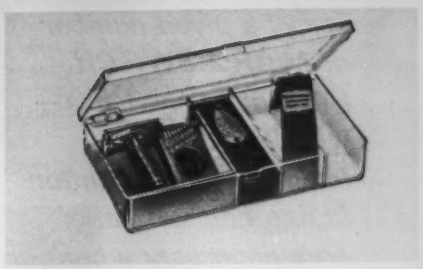
ROSS HEAT EXCHANGER

Division of AMERICAN-Standard

Circle 443 on page 19



New Gillette Special—razor, 6-blade dispenser and gold-plated lure packed in a plastic box fishermen and handymen will find useful.



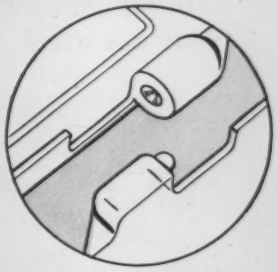
A Bright new idea in gift packaging by Gillette —custom molded by Sylvania

Chances are you're one of the many hundreds of thousands of fathers or fishermen to get a Gillette razor in the new plastic box gift case. If so, you've had a good close look at Sylvania injection custom molding.

You might have noticed that despite deep, thin-walled compartments, surfaces were smooth and clear and that in traditional Gillette fashion, the hinged top was securely latched but opened easily. And you probably guessed that the case was produced in high volume to meet the needs of America's gift-giving families, and Gillette shaving fathers.

A job like this calls for molding experience, facilities, and ingenuity characteristic of Sylvania. That's why manufacturers large and small take their custom-molding problems to Sylvania. Why don't you?

Write for this new brochure. It outlines Sylvania's complete custom-molding facilities, and might suggest how they can be put to work profitably for you. Write for information, too, on Sylvania's custom metal stampings; clad, plated and alloy wires; plated metal strip; custom wire welds, and special electronic components.



Snap-on hinges make it possible to mass-produce this Gillette polystyrene box in two pieces, quickly and economically snapped together to form the complete unit. Sylvania's ability to hold close hinge tolerances was an important factor in making this simplified design.

Sylvania's complete plastics services include mold making, compression, injection and transfer molding, and finishing and assembly operations.

SYLVANIA PARTS DIVISION

Sylvania Electric Products Inc., Parts Division, Warren, Pennsylvania

LIGHTING • RADIO • TELEVISION • ELECTRONICS • ATOMIC ENERGY

SPECIAL WIRE | METAL STAMPINGS | MOLDED PLASTIC | ELECTRONIC COMPONENTS

4-way service from one source

Circle 444 on page 19

MICRO SWITCH Precision

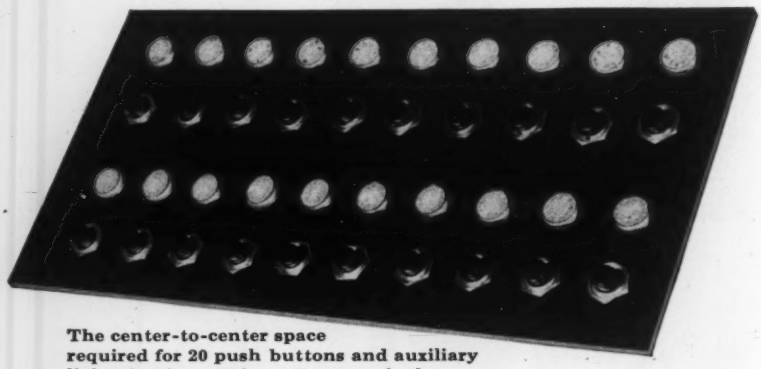
...FIRST IN PRECISION SWITCHING

Here is WHY you can

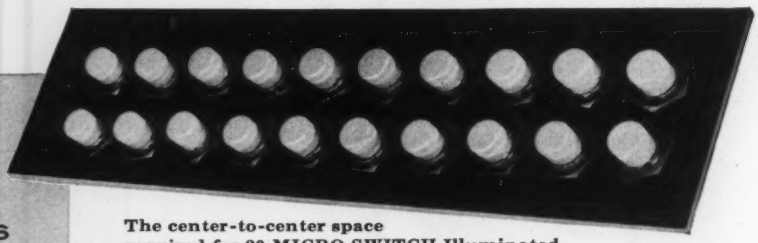
CUT PANEL SPACE **50%**

with MICRO SWITCH Illuminated Pushbutton Switches

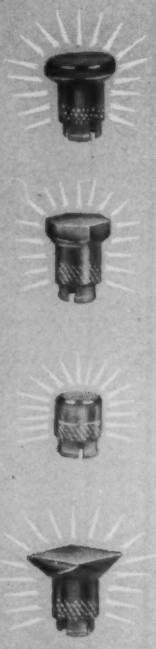
Study this illustration... it shows how you can install a given number of MICRO SWITCH Pushbutton Switches—with illumination integral with the button in one-half the panel area necessary when push buttons requiring auxiliary on-and-off lights are used.



The center-to-center space required for 20 push buttons and auxiliary lights is 4 in. x 10 in.—40 square inches.



The center-to-center space required for 20 MICRO SWITCH Illuminated Pushbutton Switches is 2 in. x 10 in.—20 square inches.



FOUR SHAPES OF PUSHBUTTONS AVAILABLE IN FIVE DIFFERENT COLORS

These four translucent button styles are available for MICRO SWITCH Type 52 PB switches.

From the top they include (1) ¾ in. round; (2) ⅝ in. hexagonal; (3) ½ in. round; and (4) ¾ in. square.

They are available in red, yellow, green, blue and white.

(Send for Data Sheet #117)

The savings in space, in time; the difference in operating ease and surety—all commend the use of MICRO SWITCH Illuminated Pushbutton Switches instead of combinations of switch and separate auxiliary on-and-off signal lights.

Here are four NEW MICRO SWITCH Illuminated Pushbutton Switches with many unique and specific features, detailed for you on the opposite page.

In addition to their other features, these switches are obtainable with any one of four different shaped buttons, in five different colors.

Read the specific details of each as set forth on the opposite page. If this information is insufficient for your purpose, ask for Data Sheets by numbers as shown on opposite page.

Switches have uses unlimited

NEW!

MICRO SWITCH Turn-to-Lock-Down Lighted Pushbutton Switch

#52PB7-T2

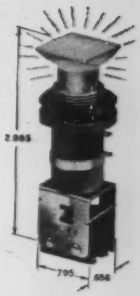
This MICRO SWITCH lighted pushbutton switch is a dual-purpose switch. Pushed straight down, it functions as a conventional momentary pushbutton. A push and clockwise twist of the finger tip holds the switch in the operated position. A counter-clockwise twist returns the switch to the unoperated position. The low operating torque required permits the switch to be mounted flush or underflush on a panel without impairing ease of operation . . . This versatile switch can take the place of conventional push button, holding relays and separate indicator lights in many applications. Or it can take the place of an alternate-action pushbutton and provide optional momentary action.

CHARACTERISTICS: Operating force 34 oz. max. Pretravel .220 in. min. Overtravel .120 in. max. Two subminiature switches are SPDT.

(Send for Data Sheet #116)

NEW!

MICRO SWITCH "Space Saver" Lighted Pushbutton Switch —only 2 in. max. below Panel



#52PB51-T2

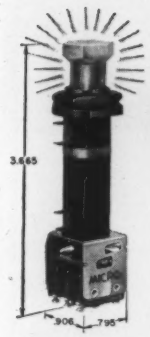
This MICRO SWITCH lighted pushbutton switch is invaluable in applications where space is at a premium. The switch has no pretravel spring mechanism which permits length to be reduced to 2.35 in. (less button). Only 2 in. max. required below mounting panel . . . This switch has a very definite snap-action "feel" and comparative high-force characteristics. Switch body contains a removable subminiature socket for the indicator lamp. Lamps are available for 6, 12 and 28 volts.

CHARACTERISTICS: Operating force—32 oz. max. Pretravel—.070 in. max. Total travel—.110 in. max. Two subminiature switches are SPDT.

(Send for Data Sheet #123)

ELECTRICAL DATA

The subminiature basic switching units used in these four assemblies have SPDT contact arrangement. Contact break distance is .010 in. min. Underwriters' Laboratories list the switches at 5 amps. 125 vac. 30 vdc ratings are: Inductive 3 amps.—sea level, 2.5 amps. —50,000 ft. Maximum inrush rating: 15 amps. 125 or 250 vac and 30 vdc.



NEW!

MICRO SWITCH Magnetic Hold-in Lighted Pushbutton Provides Three Functions

#53PB8-T2

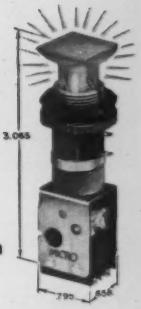
MICRO SWITCH lighted pushbutton switch combines the functions of a three-pole double-throw pushbutton switch, indicating light, and holding relay into one compact unit which panel mounts on one-inch centers, both horizontally and vertically. Thus, the cost, wiring, maintenance and added space of these separate components are eliminated . . . A 28-volt dc solenoid is incorporated into the switch shaft. After the button is manually operated, the solenoid holds the switches in the operated position until electrically released. This feature gives the designer complete freedom in panel layout by eliminating the restrictions found in conventional mechanical release designs.

CHARACTERISTICS: Operating force—35 oz. max. Pretravel—.050 in. approx. Total travel—.090 in. max. Three subminiature switches are SPDT.

(Send for Data Sheet #128)

NEW!

MICRO SWITCH Alternate Action Lighted Pushbutton Switch— for Multiple Circuit Control



#52PB61-T2

This MICRO SWITCH lighted pushbutton switch provides on-off control of up to four circuits. With each push of the button, both basic switches are alternated between actuated and unactuated maintained positions, thus providing double-pole double-throw action. Every two pushes of the button completes a cycle of operation. Variations in the long-life nylon index cam are possible which will permit a number of other sequences.

CHARACTERISTICS: Operating force—40 oz. max. Total travel—.100 in. max. Two subminiature switches are SPDT.

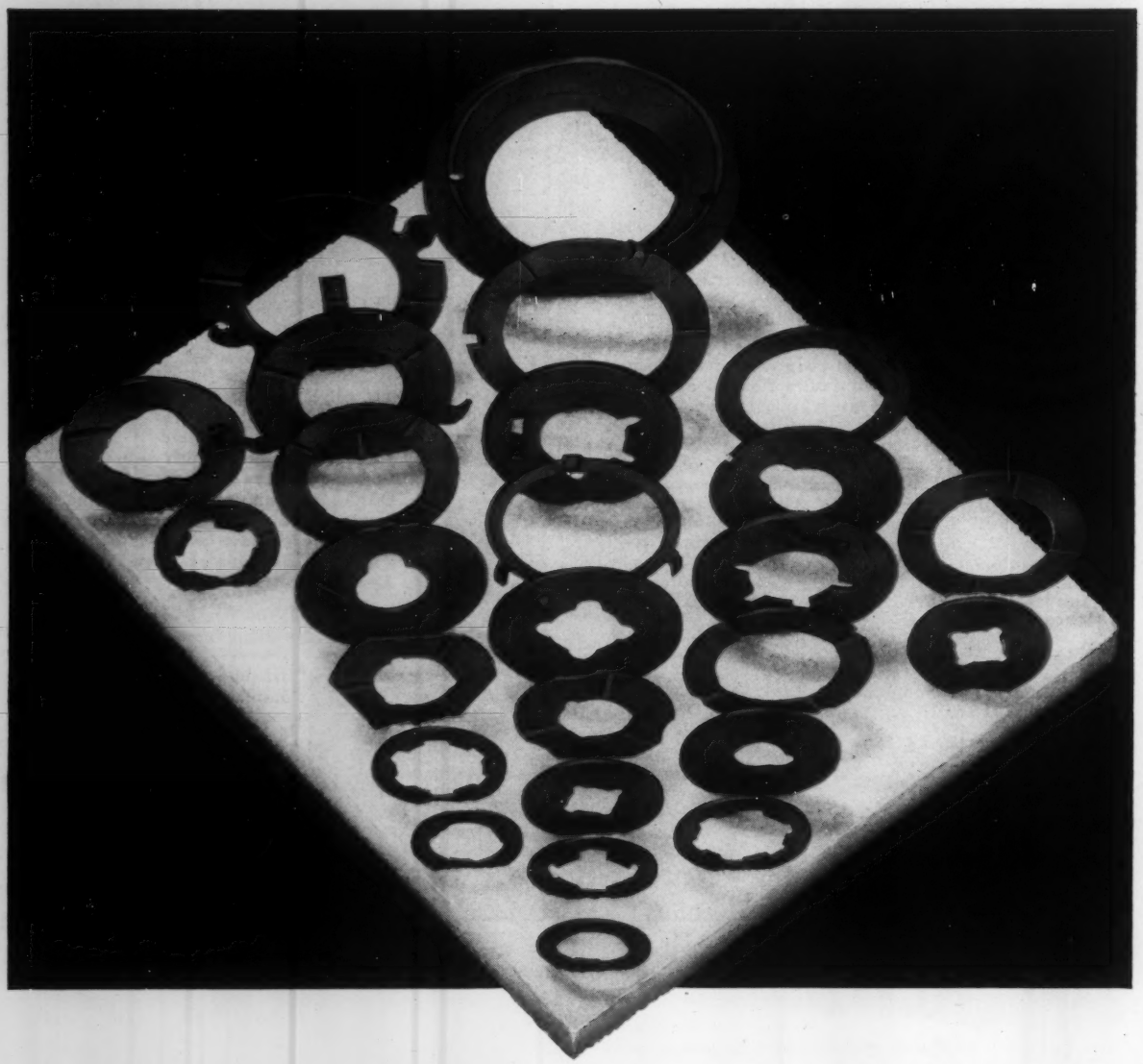
(Send for Data Sheet #124)

MICRO SWITCH

A DIVISION OF MINNEAPOLIS-HONEYWELL REGULATOR COMPANY

In Canada, Leaside, Toronto 17, Ontario • FREEPORT, ILLINOIS

Circle 445 on page 19



Variety in Precision Thrust Washer Design

Because of specially designed equipment incorporated in our manufacturing facilities, many design variations are possible in our cold-rolled thrust washers. Made of bronze, or steel with bronze on one or *both* faces, they can incorporate special holes, grooves, nibs, scallops or lugs, as required. They can be flat, spherical or special shapes, and from 1″ to 6″ O.D. Cold rolling provides exceptional hardness for heavy duty. We have large capacity and provide complete engineering service. Address:

FEDERAL Mogul L
SINCE 1899

FEDERAL-MOGUL DIVISION

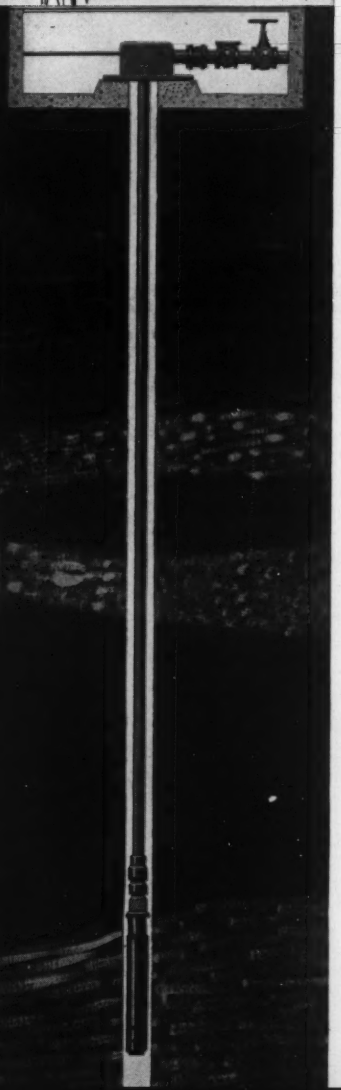
FEDERAL-MOGUL-BOWER BEARINGS, INC., 11045 SHOEMAKER, DETROIT 13, MICHIGAN

RESEARCH • DESIGN • METALLURGY • PRECISION MANUFACTURING

Circle 446 on page 19

Circle 447 on page 19→

Now you can bury your pumping problems



FAIRBANKS-MORSE
Water-Lubricated Submersible Pump

Now you can have all the advantages of a submersible pump, plus time- and performance-tested Fairbanks-Morse features.

Fairbanks-Morse submersible pumps permit well location anywhere that a well can be drilled. No unsightly installations, no costly pump housing. Nothing—absolutely nothing—need show above ground. These pumps submerged in the well below water level are practically soundless and require no line shafts, packing boxes or lubrication devices. Hence, wearing parts needing maintenance are reduced to a minimum. A single moving assembly does all the work.

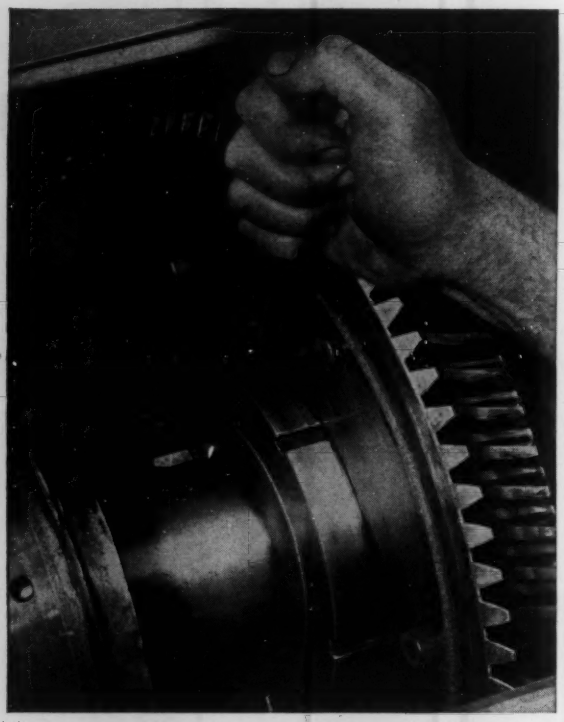
Installation is faster and more economical. The Fairbanks-Morse motor, with lifetime Copperspun rotor cooled by water and lubricated by water, gives full motor output. The well-known Fairbanks-Morse or Pomona pump bowls are combined with these wet stator motors to produce unbeatable pumping units covering a wide range of requirements as to volume, pressure, and setting depth.

For industry or community service you can place your water service trust in the F-M submersible. Contact your Fairbanks-Morse Sales Engineer and ask him for Bulletin 6910 on this time-proved submersible pump, or write today to Fairbanks, Morse & Co., Dept. MD-8-8, 600 S. Michigan Avenue, Chicago 5, Illinois.

FAIRBANKS-MORSE

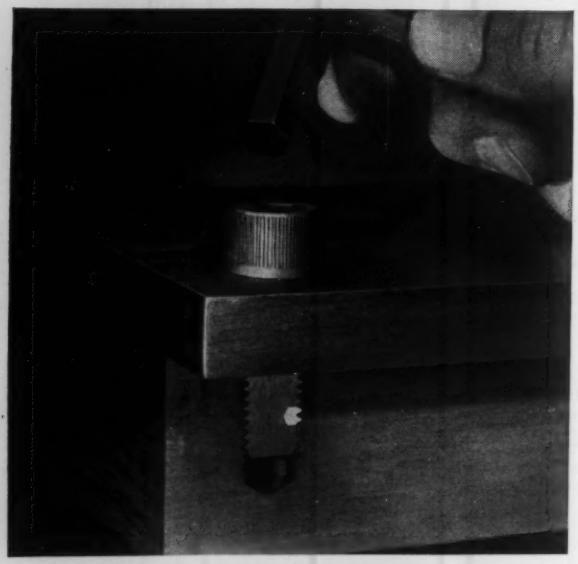
a name worth remembering when you want the BEST

PUMPS • SCALES • DIESEL LOCOMOTIVES AND ENGINES • ELECTRICAL MACHINERY
RAIL CARS • HOME WATER SERVICE EQUIPMENT • MOWERS • MAGNETOS



The ordinary fasteners securing the worm wheel to the drum shaft in this automatic screw machine loosened, causing $120 worth of damage to parts. Labor for the repair job cost $100. The ordinary fasteners were replaced with self-locking UNBRAKOS, and there has been no trouble since.

Vibration won't loosen self-locking UNBRAKO socket cap screws



HOW IT LOCKS. The tough, resilient Nylok locking pellet keys itself into the mating threads. It forces threads together and locks the screw securely—whether or not the screw is seated.

UNBRAKO socket screws with the Nylok* self-locking device eliminate fastener problems caused by vibration.

Take the drive system in the automatic screw machine illustrated above, for example. The screws originally used to secure the worm wheel to the drum shaft loosened, causing considerable damage, besides loss of production time. These have now been replaced with self-locking UNBRAKO socket head cap screws and the trouble has been eliminated.

An UNBRAKO socket screw with the Nylok self-locking device is a single unit. Just screw it into any tapped hole. Seated or not, it locks positively wherever wrenching stops. Constant vibration or endless running of a machine won't affect these self-locking UNBRAKOS. The screws will not work loose!

Write today for your copy of Form 2193, which gives catalog and technical data on the complete line of UNBRAKO socket screws with the Nylok self-locking device. Or see your local industrial distributor. Unbrako Socket Screw Division, STANDARD PRESSED STEEL CO., Jenkintown 18, Pa.

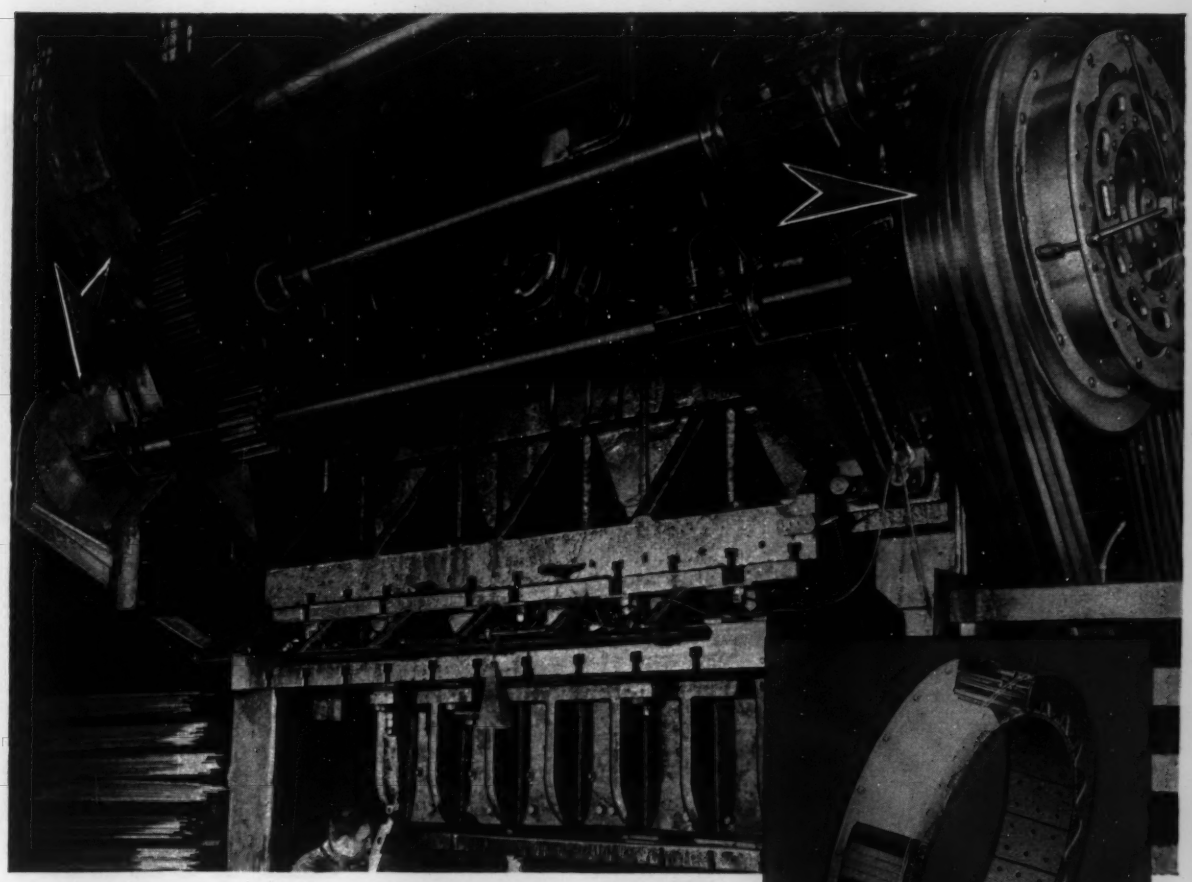
UNBRAKO SOCKET SCREW DIVISION

STANDARD PRESSED STEEL CO.

SPS

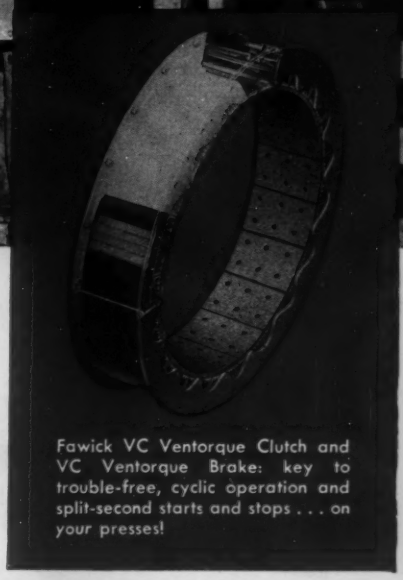
JENKINTOWN PENNSYLVANIA

*T.M. Reg. U.S. Pat. Off., The Nylok Corporation



FAWICK AIRFLEX CLUTCH AND BRAKE KEEPS THIS GIANT PRESS ON-THE-JOB

building Pullman-Standard Cars



Fawick VC Ventorque Clutch and VC Ventorque Brake: key to trouble-free, cyclic operation and split-second starts and stops . . . on your presses!

This 1200-ton press is used by Pullman-Standard in the production of freight cars for blanking and punching side and floor sheets, side stakes and hopper sheets at the rate of 80 to 100 per hour.

Tough spot for a clutch? . . . Sure, but FAWICK Airflex Clutches are designed and built for just such performance. This Pullman-Standard Airflex installation has *never* required maintenance.

Airflex Clutches and Brakes have made FAWICK the leader in making power behave . . . here's why:

increased production • maximum die protection • elimination of lubrication and mechanical adjustments • fingertip local or remote control • easy-accurate-selective "inching"

FAWICK AIRFLEX DIVISION
FAWICK CORPORATION
9919 CLINTON ROAD • CLEVELAND 11, OHIO
In Canada: Fawick Canada, Ltd., Toronto

Performance is Proof . . . ***Fawick Is Best***

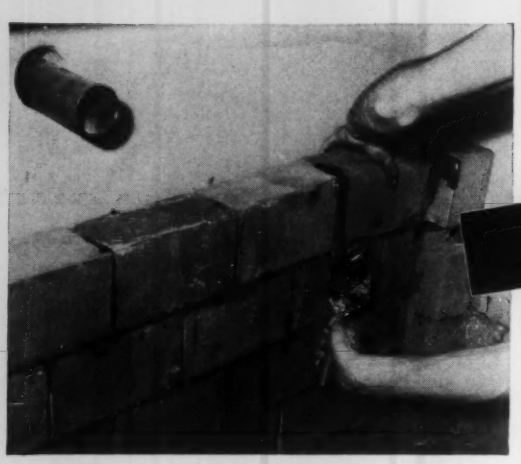
FAWICK Airflex
INDUSTRIAL CLUTCHES AND BRAKES

Circle 449 on page 19

How many of these properties

BONDING STRENGTH

Split-proof, chip-proof croquet balls and other molded products as well as board are produced from wood particles bonded with Durez resins.



ACID RESISTANCE

Cements and mortars based on Durez resins serve for bonding acid-proof brick in tanks, vats, and floors of industrial plants.

...they're all readily available in

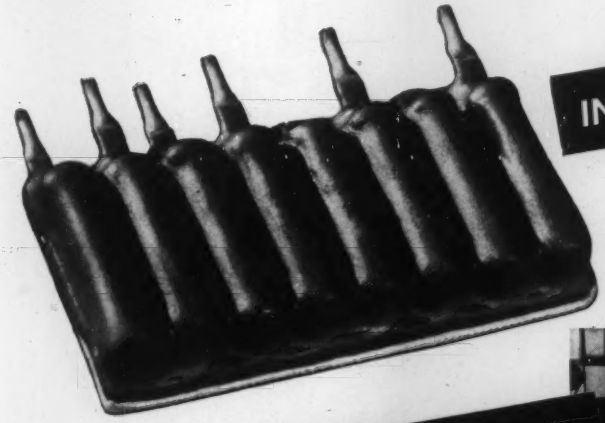
WEAR RESISTANCE

As the bonding agent in brake materials, the resin improves general wearing qualities and coefficient of friction. Linings acquire resistance to heat, water, oil, and grease from the resin.

COMPATIBILITY

Vulcanization of nitrile rubbers and substantial gains in end-use qualities result from compatibility of Durez resins with the rubber. Resins serve also to plasticize and increase hardness and wear resistance in GRS stocks.

could benefit your PRODUCT or PROCESS?



INSULATING PROPERTIES

In radio and TV components Durez resins serve as thermosetting binders, insuring uniform resistance under extremes in humidity and heat.

HEAT RESISTANCE

Foundries produce castings in shell molds of sand bonded with Durez resin having a hot strength sufficient to withstand the heat of the metal during solidification.

DUREZ PHENOLIC RESINS

FOR DESIGNERS AND ENGINEERS seeking a bonding, impregnating, or coating agent with the ability to impart important end-product characteristics, Durez phenolic resins have many interesting possibilities.

THESE SAMPLES ILLUSTRATE some of the widely varied roles they are now playing in industry. The mechanical strength of these resins and their hardness when cured are combined with remarkable properties of resistance to chemical reaction and to heat. Dielectric strength and power factor qualify them for numerous electrical applications.

THE MOST DESIRABLE type and form of Durez resin for any purpose is determined by the processes which will be used, and the available conditions of temperature and pressure in addition to the end-product properties required.

OUR COMPREHENSIVE BOOKLET on the performance of phenolic resins in industry has recently been published in a new edition. For a free copy, please write on your letterhead for "Durez Industrial Resins."

DUREZ®

Plastics and Resins that Fit the Job

DUREZ PLASTICS DIVISION

HOOKER ELECTROCHEMICAL COMPANY

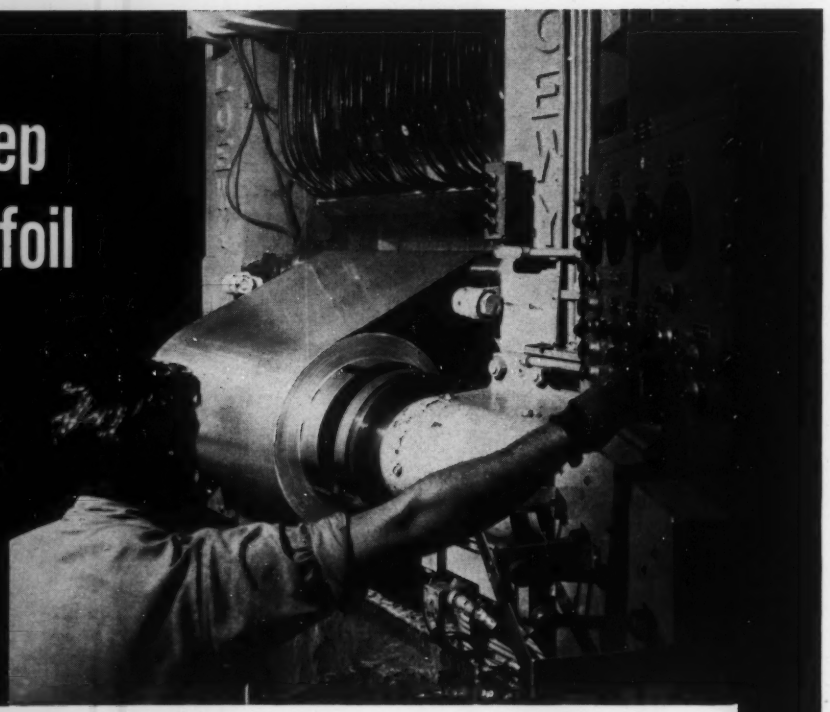
508 WALCK ROAD, NORTH TONAWANDA, N. Y.

HOOKER CHEMICALS PLASTICS

Circle 450 on page 19

how to keep aluminum foil from shattering

... at miles per hour!



Kaiser Aluminum & Chemical Corp. increased annual production of aluminum foil 50% at its Permanente, California plant through installation of a four high foil mill. This mill reduces aluminum strip in thickness from .026 to .00025 of an inch at speeds up to 3000 fpm.

At 35 miles per hour, excessive strain at any of the several reduction stages would shatter the extremely thin foil. From the original payoff reel through to the final rewind, uniform tension is provided by Reliance V★S Drives.

Reliance engineers built this drive specifically for this mill, to provide the constant uniform tension which is so important.

This application is typical of the many diversified jobs that Reliance V★S Drives are called upon to perform. There is a Reliance V★S Drive to fit your application.

D-1862

***For further details, write* Dept. 28A**

Main control room—Where Reliance equipment provides more than 2,900 hp. to drive this mill.

RELIANCE ELECTRIC AND ENGINEERING CO.

CLEVELAND 17, OHIO • CANADIAN DIVISION: WELLAND, ONT.

Sales Offices and Distributors in Principal Cities

NOTHING *can equal Stainless Steel*

in its unique combination of properties

No other design material can match Stainless Steel in its combination of desirable properties: corrosion resistance, strength, hardness, beauty, cleanability and easy fabrication. For a reliable source of supply, United States Steel offers you the widest range of types, finishes and sizes.

UNITED STATES STEEL CORPORATION, PITTSBURGH
AMERICAN STEEL & WIRE DIVISION, CLEVELAND
COLUMBIA-GENEVA STEEL DIVISION, SAN FRANCISCO
NATIONAL TUBE DIVISION, PITTSBURGH
TENNESSEE COAL & IRON DIVISION, FAIRFIELD, ALA.
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WAREHOUSE DISTRIBUTORS
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

USS STAINLESS STEEL

SHEETS • STRIP • PLATES • BARS • BILLETS
PIPE • TUBES • WIRE • SPECIAL SECTIONS

USS

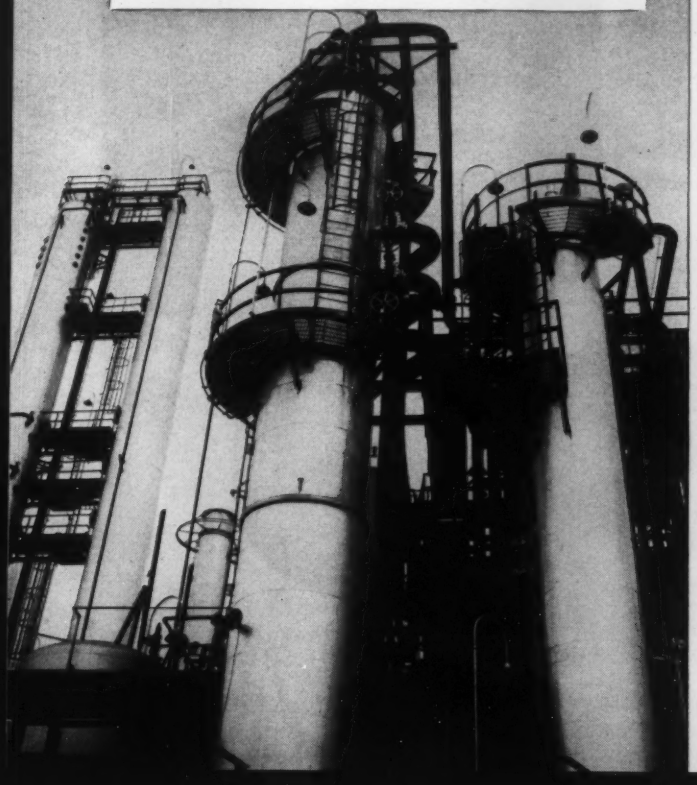
UNITED STATES STEEL

For Sanitation

Food juices are incredibly corrosive, so some restaurants have a lot of trouble in their cold storage rooms because the racks corrode and harbor bacteria. Eastern Steel Rack Company makes racks from Stainless Steel. They are easy to keep clean; and, for all practical purposes, they *never* wear out.

For Corrosion Resistance

This petrochemical extract fractionator was originally made from carbon steel . . . but corrosion ate through the plates and put it out of service in *just two months.* They lined the tower with type 316 Stainless Steel. When examined, the tower had been in service 21 months, and the Stainless was still in good condition.



For Cleanliness

Hawthorne Paper Company, Kalamazoo, Mich., goes to extraordinary lengths to guard against color contamination. Old wooden tanks were thrown out and replaced with Stainless Steel. According to the men at Hawthorne, the Stainless has absolutely no contaminating effect, and it's easy to fabricate.

Circle 452 on page 19

drive gears in BOLENS TRACTORS

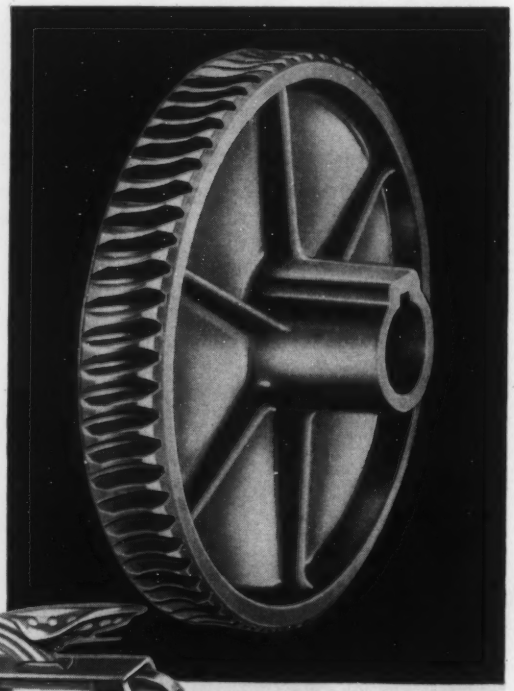
toughness of MUELLER BRASS

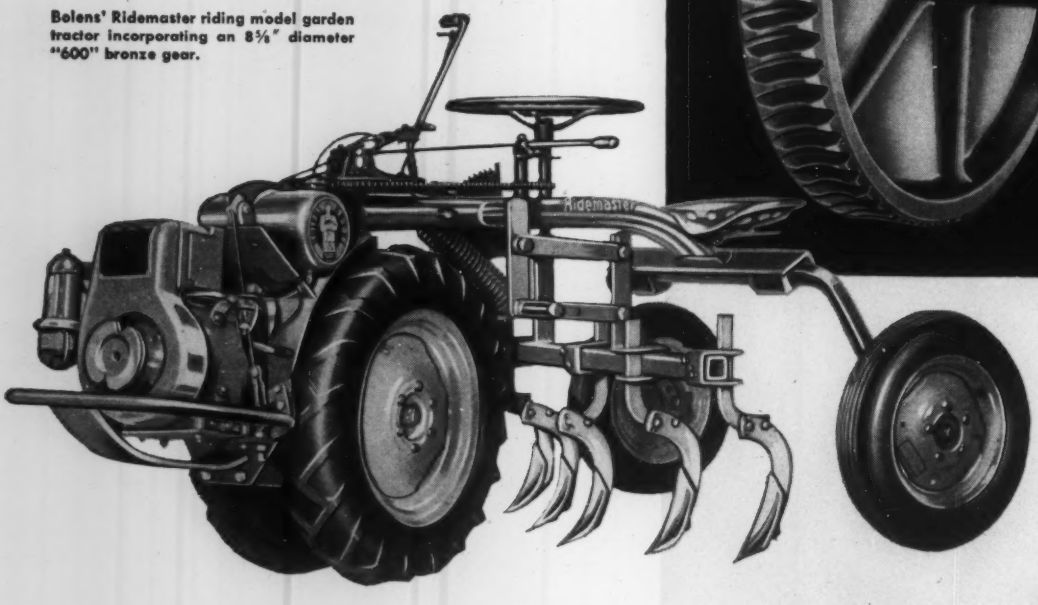
"600" series bronze alloys

Forged bronze gears made from tough, long-wearing Mueller Brass Co. "600" bearing alloy are proving their ability to withstand punishment in the popular outdoor power equipment manufactured by the Bolens Products Division of Food Machinery and Chemical Corporation, Port Washington, Wisconsin. The Junior and Super Mustang rotary tillers, all employ "600" main drive gears to dependably transmit engine power to drive assemblies. The going is rough for equipment of this type in cultivating or tilling heavy soil—but Bolens has a record for ruggedness and, on these and many other Bolens products as well, Mueller Brass Co. "600" gears help make possible that fine performance.

Mueller Brass Co. "600" bearing bronzes are available as forgings, or in rod form. They provide unusually high tensile strength, a dense structure, good resistance to corrosion, and excellent bearing properties. Because of their good machining qualities, the "600" series bronzes can be finished readily—usually at substantial savings in COST.

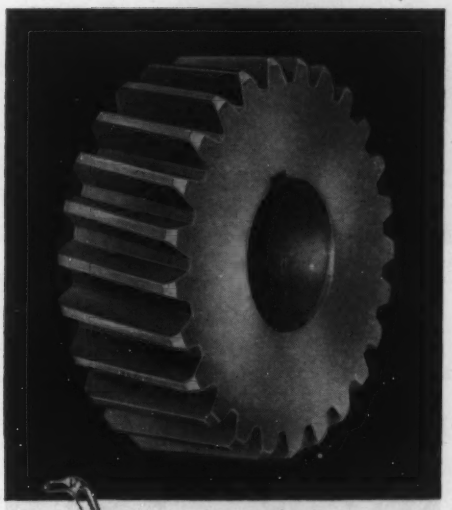
It will pay you to investigate these alloys for your products . . . why not write today for full information.





Bolens' Ridemaster riding model garden tractor incorporating an 8⅝" diameter "600" bronze gear.

and TILLERS prove CO.



Bolens' Super Mustang rotary tiller incorporating a 25-tooth "600" series bronze worm gear.

• WRITE TODAY FOR THE ENGINEERING MANUAL YOU NEED

Mueller Brass Co. Forgings Engineering Manual H-58565 ☐

Tuf Stuf Aluminum Bronze Alloys Engineering Manual H-58563 ☐

"600" Series Bearing Alloys Engineering Manual FM-3000 ☐

Copper Base Alloys in Rod Form Engineering Manual FM-3010 ☐

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40 OUR 40TH YEAR MUELLER BRASS CO. 1917-1957

MUELLER BRASS CO.

PORT HURON 20, MICHIGAN

METALS AND ALLOYS REVIEW

by FRANK M. LEVY

Vice-President and Director of Research

One of the most interesting things about our 600 series bearing alloys is the great variety of products in which they find application. In the advertisement to the left you can see how the Bolens people put 600 gears to work in their rotary tillers and garden tractors. Those gears are big, take a lot of abuse, and meet the job needs perfectly. We also make a lot of small parts, too, that have been specified because of the many unusual properties of this series of alloys.

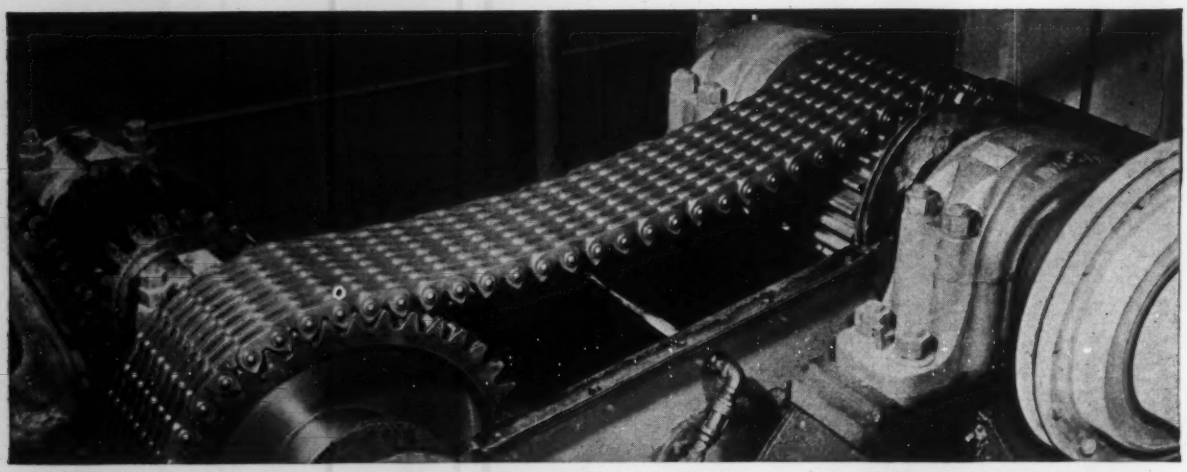
One good example that comes to mind is a shaft bushing on a rotary selector switch that we make for an instrument manufacturer. This selector is used for switching sound-powered telephone circuits aboard Naval vessels. One of the most important considerations in the choice of 600 alloy for this bushing was its resistance to abrasive action on and against a rubber "O" ring. The acceptance test required a stainless steel shaft riding in the bushing to rotate "dry" for a minimum of 50,000 cycles consisting of 360° rotation clockwise followed by a 360° rotation counter-clockwise. The "O" ring must still form a watertight seal at the end of the test. Our 602 alloy was the only one of several materials tested that met the specs. That was pretty good evidence in itself of resistance to abrasion, but, in addition, this customer also found that the use of 602 eliminated the headaches they previously had with seizing and galling.

The pounding action caused by the indexing mechanism attached to the shaft used to give them no end of seizing troubles. The chief product engineer is extremely happy about the way our alloy is performing. Mention was also made of the fact that the corrosion resistance of 602 was mighty impressive. In this application, the alloy passed the 200-hour Navy salt spray test with flying colors.

So, big or small, it seems that there is no end of applications for 600 series alloys. We even have parts working in a machine that slices frankfurters as well as gears in fishing reels. So, it seems that 600 runs the gamut from "red hots to reels". Well, it looks like the end of the page is here again, so I'll close for now. However, if you have any problems or questions about non-ferrous alloys or you're having trouble getting desired performance from a part, why not drop me a line here in Port Huron, and possibly I can be of some service. Send a part print along if you like, and we'll be glad to make proper recommendations.

Thanks again for your time.

Circle 453 on page 19



HIGH SPEED. Traveling at speeds as high as 5000 fpm, silent chain drives readily accommodate the extreme peak loads without losing their better-than-98% efficiency.

How LINK-BELT silent chain drives survive industry's roughest requirements

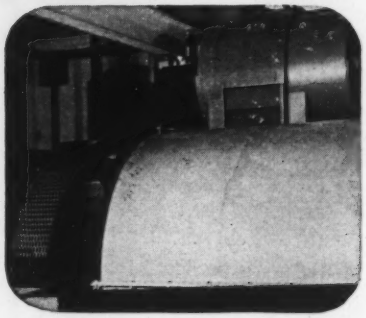
Would your drives do as well?

On applications like these and scores more, no other type of drive is the equal of Link-Belt silent chain. Ask your nearby Link-Belt office for a copy of comprehensive 88-page Data Book No. 2425.

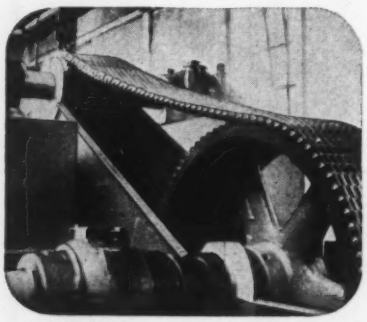
LINK-BELT

SILVERSTREAK SILENT CHAIN DRIVES

LINK-BELT COMPANY: Executive Offices, Prudential Plaza, Chicago 1. To Serve Industry There Are Link-Belt Plants, Sales Offices, Stock Carrying Factory Branch Stores and Distributors in All Principal Cities. Export Office: New York 7; Canada, Scarboro (Toronto 13); Australia, Marrickville (Sydney), N.S.W.; South Africa, Springs. Representatives Throughout the World. 14,679-A

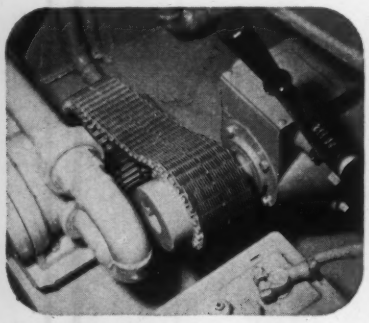


LARGE OR SMALL HP. On a 300 hp drive like this or at fractional hp, silent chain is always lower in ultimate cost.

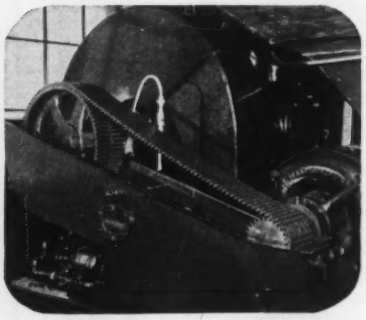


LARGE RATIOS. Link-Belt silent chain operates efficiently on extremely short centers at ratios as high as 10-to-1.

ADVERSE OPERATING CONDITIONS. Heat, humidity and cold have little effect on Link-Belt silent chain drive performance.

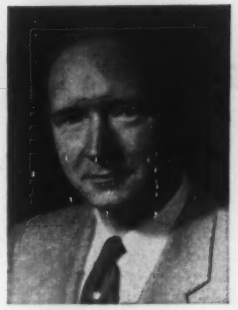


LIMITED SPACE. Easy to assemble in close quarters, Link-Belt silent chain permits built-in drives, compact housings.



LONG LIFE. This drive is 16 years old and still going strong. Not unusual—many others have lasted twice that long.

MACHINE DESIGN
August 8, 1957



Toward Professional Unity

ENGINEERS are not so much unorganized as disorganized. Such is the obvious conclusion of anyone who observes the relative coherence of other professions.

Recently, on this page, we pointed to the numerous types of organizations open to engineers, ranging all the way from true-blue conservative professional societies to unabashed labor unions. At the moment the latter groups, having suffered temporary setback, undoubtedly are planning new stratagems to lure reluctant engineers into their fold.

It is therefore encouraging to note that the conservatives are not standing still. The presidents of two major societies, the AIEE and ASME, have declared in favor of a plan for more coherence at the professional end of the spectrum.

The plan contemplates closer co-operation, and agreement on specific areas of activity, among three existing groups: Engineers Joint Council, Engineers' Council for Professional Development, and National Society of Professional Engineers. Up to now, overlapping functions and duplication of effort have weakened the effectiveness of each and have led to confusion regarding the role of each group.

Briefly, the scope of each would be defined in this way: Technological affairs would come under EJC, educational under ECPD, and professional under NSPE. The idea makes a good deal of sense, especially since it does not involve the creation of an entirely new organization, as has been proposed by some.

The first two groups, EJC and ECPD, are each backed by leading engineering societies representing many design engineers. As federations at a society management level, these groups may appear somewhat remote to members-at-large of constituent societies. Yet they represent the only potential means, especially if lined up with NSPE, the registered engineers group, for bringing some semblance of unity to our profession. They need backing from the grassroots.

Here is an opportunity to show whether or not you as an engineer are genuinely interested in professional unity. If you like the proposed plan of co-operation, write and tell the president or council of your own society; if you have a better idea, tell them about it.

True professional unity, or coherence, can be achieved only if engineers at the grassroots want it badly enough to do something about it. Do you?

Colin Carmichael

EDITOR

Profitable Fields for

New Product Development

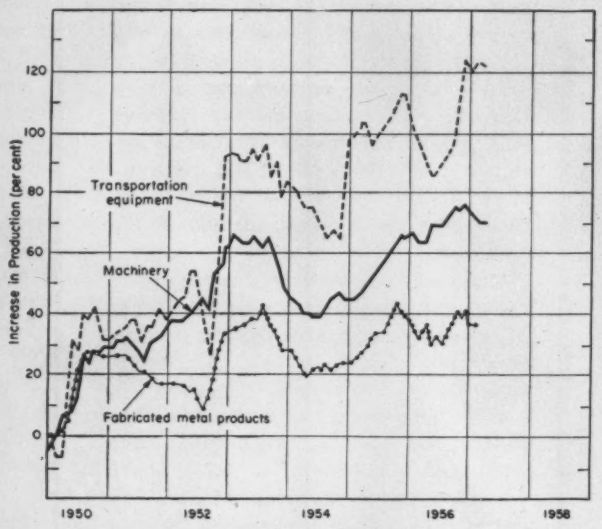
By Philip R. Marvin
Manager, Research and Development Div., American Management Association New York

SUCCESS of new products that appear in the next five to ten years will depend upon a combination of factors. These factors include the development of natural resources, technological advances, and new-product opportunities created by population growth, changing patterns of culture, and the like. Growth to be anticipated in specific new product lines is indicated, to a degree, by a study of the growth of older products of the same general nature, Fig. 1.

For example, the growth rate of residential clothes-dryer production has averaged over 40 per cent per year since 1947. Similar growth rates are shown by titanium, television receivers, power brakes, antibiotics and detergents. Averaging 30 to 40 per cent yearly growth are tape recorders, electric shavers and air conditioners. Home freezers, electric blankets and diesel locomotives represent a group that has averaged 20 to 30 per cent.

Unfortunately, not all product lines have reflected growth. An overall analysis of economic patterns reveals peaks and chasms, side by side. These will be repeated in days to come. Those responsible for a company's future must establish and follow a carefully organized program designed to steer new developments in directions that will result in profits. Successful planning is based upon seven important steps:

Fig. 1—Right—Comparison of growth for three representative fields of durable manufacturing indicate wide variations. Chart is from Federal Reserve Indexes, using a base period from 1947 to 1949 as 0; values are adjusted for seasonal variations.



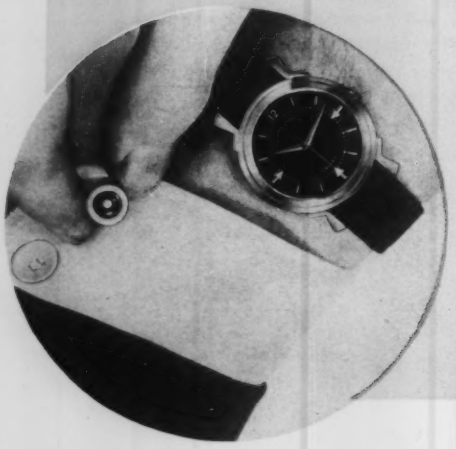


Fig. 2—Left—Subminiature, 0.05-oz battery powers first electric wrist watch. Successful development of tiny battery permitted radical departure from conventional watch design. Photo, courtesy Hamilton Watch Co.

In any planned campaign for new product development, certain areas are worth watching closely because they have greater profit potential than others. This article, third in a current program, examines these high-potential areas and tells which trends to watch.

Fig. 3 — Above — Pocket-size TV camera was designed around transistors, transistor circuitry, and a ½-in. camera tube. One-pound unit has photoelectric lens-iris control for changing light levels. Photo, courtesy Radio Corporation of America.

1. Analyze today's research developments.
2. Calculate probable impact of these developments on our way of life.
3. Determine how to capitalize upon a new development.
4. Know alternative courses of action.
5. Know trends that influence decision-making.
6. Capitalize on selection of best available course of action.
7. Apply vigorous and concentrated effort to development.

In following these steps to analyze and utilize new developments, six questions must be asked and answered:

1. What is new?
2. How can it be used?
3. Can we use it?
4. What are the alternatives?
5. What are the trends?
6. What action should we take?

Appraisals of new developments are essential to future planning. Such appraisals serve to jog management thinking, break down complacency, and establish perspective for planning in a competitive economy.

What is New?

The tendency is to regard scientific developments as events that affect someone else's business. Realistic thinking forces an awareness of the fact that most technological developments, sooner or later, have far-reaching effects on business activity in general. Thoughtful analysis of some current developments will reveal the potential breadth of their impact on business. In certain general areas, research and development have been responsible for a vast array of commercially successful new products. When searching for new product ideas, the following areas should be carefully explored due to their proven high potential.

Miniaturization: One of the most significant design trends today is that toward miniaturization. Its influence is reflected in both industrial goods and consumer products. Miniaturization represents an attempt to pack greater performance into less space. To achieve this calls for the combined efforts of the scientist and the design engineer. Two recent products illustrate this design trend.

A few years ago, had someone suggested an electrically powered wrist-watch, the idea would have seemed preposterous. Yet, today, you can purchase a wrist-watch driven by a tiny battery and an electric motor. This watch, Fig. 2, represents a milepost in design achievement. It reflects truly creative engineering. Not only was it

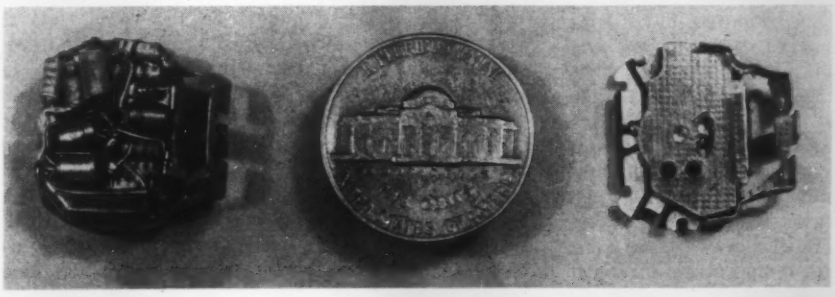


Fig. 4—Hearing aid, designed to be worn entirely in the ear, uses three transistors and a 1.3-v battery. Life of miniature battery is 50 hr. Photo, courtesy Sonotone Corp.

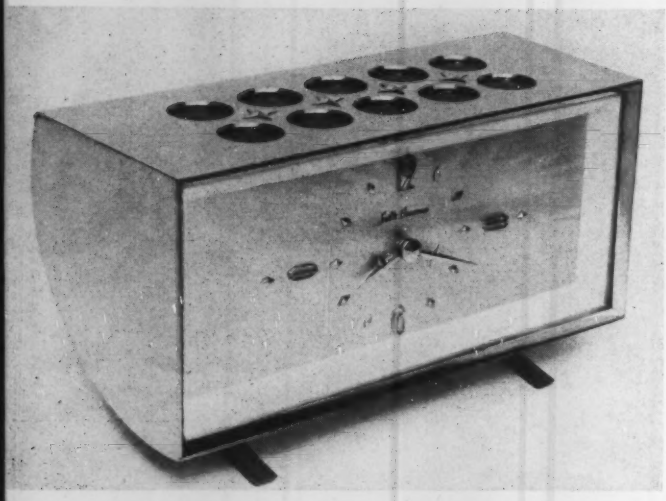


Fig. 5—Solar clock has silicon solar cells that charge an accumulator cell. One day of incandescent light or sunlight stores sufficient energy for a month of operation. Photo, courtesy General Time Corp.

necessary to develop a unique source of power in the form of a special battery, but it was also necessary to devise an equally unique electromechanical system to utilize this power effectively. The result is a combination of superior accuracy in a timepiece and freedom from dependence on periodic winding.

A second development reflecting the trend toward miniaturization is a portable TV camera for commercial and military use. The one-pound camera, Fig. 3, has a photoelectric system that automatically adjusts the lens opening to the available light. Another example of miniaturization is a hearing aid worn completely within the ear, Fig. 4.

These items are but three of many new developments in consumer and industrial product lines appearing on the market. The most significant aspect of this trend toward miniaturization is the future impact that it portends for the individual corporation. Awareness of these trends affords an opportunity to assume a leadership position in capitalizing upon the profit potential that is inherent in new technology.

The trend toward miniaturization has far-reaching implications for today's product lines. Few corporations can escape the impact of this technological trend. It extends to materials, methods, skills and energy sources.

Materials: Materials of every nature have demonstrated tremendous advances. Considering the metallic field only, titanium, magnesium and beryllium have achieved such industrial prominence that it is hard to believe that only a relatively few years ago they were regarded as rare metals. Niobium is a relatively unfamiliar metal. Notwithstanding its anonymity, its production is measured in tons. At the present time niobium is used in the fission zone of nuclear reactors. It is a metal possessing a high melting point, high-temperature strength and excellent corrosion resistance to acids. Its future looks promising.

Cerium, another metal, is finding increasing use in aircraft parts. Boron output has trebled in the past ten years as it found markets in the atomic-energy field as control elements and for shielding purposes. Boron is also a constituent of rocket fuels. Tantalum is finding increasing use in metal-cutting and in electrical capacitors. Thorium is used not only as a source of fissionable uranium but for the production of refractories, vacuum tubes, lamp filaments, and magnesium alloys.

One of the most interesting developments is the rapid advance in lithium metallurgy. Lithium has the interesting physical property of being the lightest of the metallic elements. It is used in lubricants, ceramics, organic chemicals, air-conditioning, glass, pharmaceuticals, dry-cells, and as an energy source.

Rapidly expanding technological developments in aircraft, electronics, nucleonics, and other fields of industrial endeavor, have resulted in the growing importance of these and other previously rare metals. The development cycle for these metals has followed a familiar pattern. As new and interesting properties of these materials have been disclosed by scientific studies, potential applications have become apparent. This has focused attention on the need for better extractive and production techniques to reduce costs. Reduced costs, in turn, have opened new applications.

The list of lesser-known metals coming to the forefront is growing rapidly. Others to watch include barium, cadmium, germanium, rhenium, and rubidium.

Energy Sources: The public is conscious of advances in the development of solar and atomic energy. It is of greater importance to recognize that tremendous strides have been taken in commercializing these energy sources.

It has been common knowledge for a great many years that the sun releases energy to the earth's surface at the equivalent of 250 Btu per square foot per hour—which is far from an inconsequential amount of energy. Rapid strides are being made in harnessing this energy. Effective solar-heating systems for homes have been developed which store sufficient heat during a single daytime period to heat a residence for several days and nights.

A device has been developed that can be mounted on a telephone pole and that will convert sunlight into sufficient energy to power a transmission line during the daytime hours; at the same time it charges a storage battery to provide around-the-clock energy. An experimental installation is in operation in Georgia. A table clock, Fig. 5, has been developed that will operate a month on the "charge" received from one day of exposure to light.

In recent years, interest in atomic energy has been largely focused in the direction of central-station power production. However, potential interest in an atomic battery for many applications

is of considerable importance. The atomic battery utilizes emitted particles or radiation to activate a second material such as cadmium sulphide, which converts the nuclear emission into a radiation of wave length such that it can be converted into electrical energy by other materials such as selenium. Batteries of this type provide a constant source of power over a period of many years.

Development of central-station generated electric power has taken a turn toward the application of controlled thermonuclear reactions. The first step in this direction has already been taken. The development of controlled fusion is of considerable significance to the engineer. Controlled fusion may ultimately permit the direct conversion of nuclear energy into electrical energy without the need for heat exchangers or generators.

It is interesting to note that 2.2 lb of deuterium, or heavy hydrogen, can produce approximately 100 million kilowatt hours of electricity. The total output of electric utilities in the United States in 1956, including steam and water-generated power, was a record 601 billion kw hr. This is the equivalent of the power that could be produced by 66 tons of deuterium.

Agriculture: Technological developments by other industries have made serious inroads on the market for agricultural products. The development of plastics for shoe soles has absorbed over 60 per cent of the market for leather for this purpose. Producers of natural fibers have suffered a similar loss of market. Rayon and other synthetic fibers, including nylon, Dacron, Acrilon and others, now supply nearly 50 per cent of the textile market formerly enjoyed by the natural fibers. Another example is found in markets lost by the development of synthetic detergents, which are direct competitors of soap. Synthetic-detergent production today has absorbed some two-thirds of the soap market.

One of the real causes of today's farm problem is an earlier failure to apply research to farming operations. Today this trend has been reversed. Industries closely identified with agriculture and food products must make careful note of new developments as they appear upon the horizon. One of the significant developments of agricultural research is the increasing use of automatic equipment on the farm. Through the efforts of the mechanical engineer and the agricultural scientist, a single farmer today can accomplish as much work in a given time as five farmers could complete 50 years ago. These mechanical products of research and engineering till the soil, plant seeds, spray crops—thereby accelerating pollinization as well as destroying insects and bacteria—and assist in harvesting the crop. Automatic equipment feeds and milks the cows and tends the chickens.

Packaging of raw eggs in plastic containers, development of dehydrated foods, and conversion of cellulose and sawdust into sugar for human consumption are representative developments. Entire new areas of commercial importance are developing as new antibiotics and hormones are extracted from agricultural products.

Fibers and Textiles: Developments in the textile industry extend not only to fiber synthesis, blending, spinning, weaving, and converting of textile products, but to the construction of fabrics. It is in this latter area particularly that radical changes, having the potential of altering the entire industry, appear at the forefront of textile research and development.

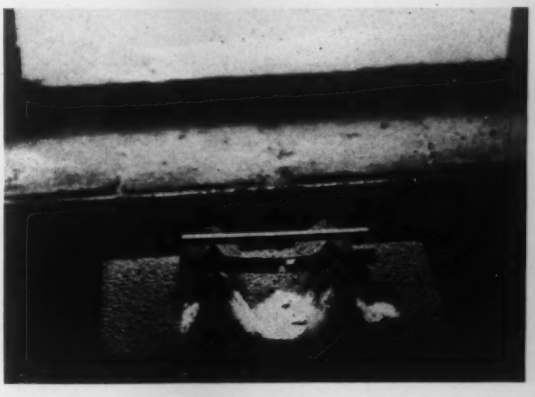
A relatively recent development is that of nonwoven fabrics. All of the operations associated with the production of nonwoven fabrics can be built into one machine. Single fibers or blends of fibers, such as nylon, cotton and acetate, can be fed into the machine and a completed fabric delivered ready for the cutter. These nonwoven fabrics permit close control of physical properties and the costs are low. Nonwoven fabrics are lightweight, have a smooth surface, high porosity, absence of raveling, high absorbency, excellent wet strength and heat sealability.

Accompanying the development of nonwoven materials in the textile field are closely related developments in the paper industry. Today it is difficult to tell whether a table napkin is a modified paper product or a modified textile product.

These developments are particularly significant to the design engineer. Once research and pilot production have established basic advantages of a particular material, the design engineer must give production equipment careful study. Here the opportunity for improvements with great commercial significance is often revealed. New developments in the textile and paper industry present major areas for further work by equipment designers in years ahead.

Technical Tools: Advances in the technical tools used by scientists and engineers and in a produc-

Fig. 6—Pyroceram, a new glass derivative, may be harder than steel, lighter than aluminum, and nine times as strong as plate glass. High-temperature strength is demonstrated by furnace test that melts companion copper bar and causes steel bar to sag from its own weight. Photo, courtesy Corning Glass Works.



tion process itself often indicate future trends. Looking back, the development of the electron microscope serves to demonstrate the relationship between technical tools and subsequent developments in profitable product lines.

To do a better job, we need to know more about how things work. We need to know more about the parts that make up the whole. We need to know how they are arranged and how they operate. The electron microscope facilitated probing into these relationships to a degree impossible before.

Fig. 7—Research in superconductivity—the ability of some metals to conduct current, with no resistance, at extremely low temperatures—has led to the cryotron at the right. The tiny unit may replace transistors, left, and vacuum tubes in future electronic devices. Photo, courtesy Massachusetts Institute of Technology.

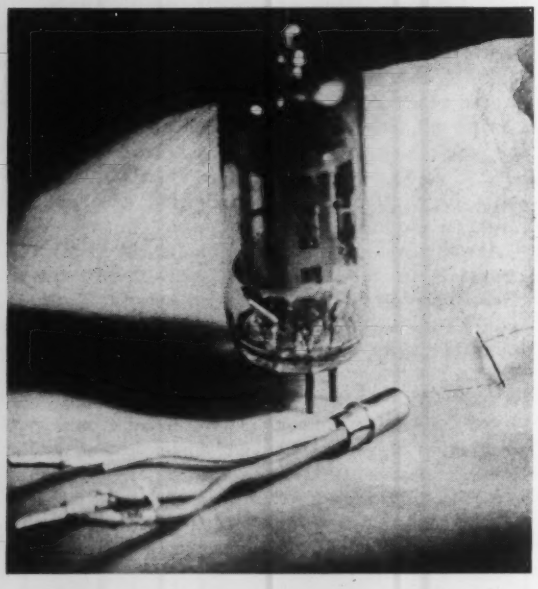
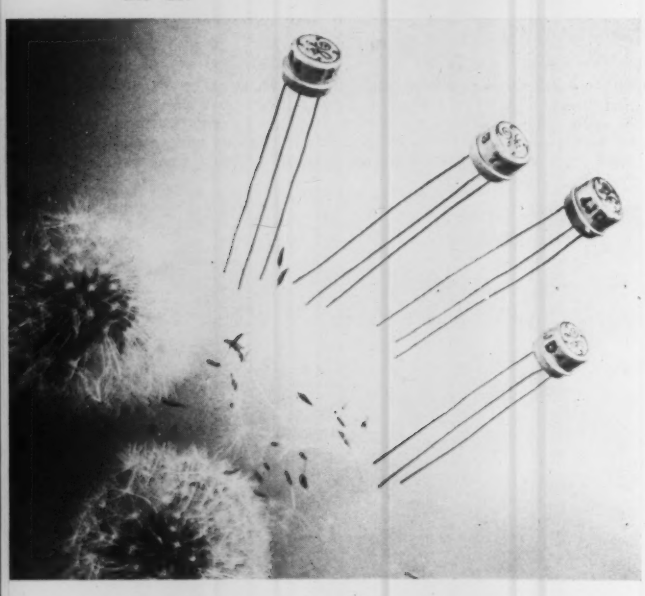


Fig. 8—Below—Research and development are very active in the electronic-component field. These new high-frequency, high-temperature silicon triodes represent another step in transistor development. Photo, courtesy General Electric Co.



Ability to distinguish the structure of small objects is limited by the ability of the eye to distinguish between two points or lines separated by a short distance. Unaided, the limiting resolution of the eye is approximately 0.1 mm. The conventional light microscope improved the resolution of the human eye by 500 times. The ultraviolet microscope improved resolution, through the aid of photograpic techniques, 1000 times. The development of the electron microscope increased the resolution of the human eye by 100,000 times. As a result of these developments, studies of small structures have been made possible.

The commercial results of these studies are well recognized today. Studies of carbon black resulted in the development of rubber products possessing high electrical conductivity. The electron microscope provided the first opportunity to study the viruses and led to the development of antibiotics. Developments in soaps, resins, fibers, and aerosols represent other areas where the electron microscope has made basic contributions.

New technical tools are constantly being developed. One of the most interesting from the standpoint of the layman is the development of the music synthesizer. Until relatively recently, scientists and engineers were dependent upon the various musical instruments for reproduction of what, in psychological terms, are designated pitch, loudness, timbre and time. Sound engineers break these down into a group of physical characteristics identified as frequency, intensity, growth, duration, decay, portamento, wave-form, vibrato, and deviation. Specified in terms of these properties, any tone may be described in all of its aspects.

The electronic music synthesizer is designed to generate each of these characteristics. Tone characteristics are preset in coded form and introduced into electronic circuits which are capable of reproducing these interrelated effects. Mankind now has at its disposal a device which permits relatively unlimited experimentation in tone and rhythm. The music synthesizer provides a method of creating tones which can be used in the design of a wide range of audio equipment.

Transportation: The transportation industry is feeling the full impact of technological development. The use of the rocket introduces a new controlled-power source. Rocket development is big business for both large and small companies.

Rockets that can travel at speeds of 3000 mph are now feasible. At increased speeds, not only in the air, but on the land and the sea, mechanical and electrical controls will take over operations formerly performed by the human operator. New materials of construction will be utilized, Fig. 6. These materials will reflect combinations of today's commercial metals and plastics and an increased use of glass fibers, other inorganic fibers, new metals and new plastics.

Solid-State Physics: Exploratory studies of the solid state are making familiar substances available in new forms and utilizing new properties of familiar materials, Fig. 7. The scientist and the engineer have created by artificial means materials already available in our natural environment. Some years ago, scientists developed synthetic sapphires with the same chemical and physical characteristics as sapphires found in nature. The synthetic sapphires have been made available at a lower cost than their natural counterpart and opened up many new applications. Similarly, synthetic germanium crystal production made widespread application of transistors possible, Fig. 8.

Recently a new step has been taken in the process of synthesis. Boron nitride has been produced in a state which was and is unknown in the world of nature. Under high heat and great pressure, boron nitride has been synthesized in a crystal structure common in nature to the diamond. This new form of boron nitride possesses hardness and resistance to high temperatures. Scientists have again taken the first step in the development of a potentially wide range of new materials.

Productivity: Increasingly, productivity becomes a matter of major concern. The machine has made increased productivity possible. As a result of an increased volume of goods turned out per man-hour, people have the choice between additional goods and shorter working hours. Subsequent developments in equipment, materials and automatic operations will raise productivity to new levels.

These developments present a real challenge to the engineer and to the scientist. The uniqueness of the products developed will determine to a large degree the extent to which the individual chooses leisure rather than increases consumption of physical goods. In either case the balancing of leisure and productivity in the future will change the balance existing among the service trades, manufacturing, the professions, and the arts. Cost patterns will shift. The scientist and engineer will play a substantial role, recognized or not, in shaping the future.

Growth Potential of the Economy

Coupled to any consideration of the potential industrial significance of technological development must be an analysis of the economy's growth potential. Over the next ten years, total spending for goods and services is expected to increase approximately 40 per cent. Using specific figures to illustrate this growth, the gross national product, which in 1955 was $402 billion, is anticipated to achieve a level in the vicinity of $550 billion by 1965. This, measured in terms of 1956 dollars, reflects an increase of 37 per cent.

A sizable share of this growth will be attributable to increased research expenditures. Industry, government, universities, and nonprofit organizations spent nearly $8 billion for research and development during 1956. Industry's share of this total ran slightly over $5 billion.

Looking ahead, industry will spend an estimated $7 billion on research and development during 1957. For federal research and development $3.4 billion has been allocated for 1958. Research and development have outstripped overall economic growth at a ratio of about 7 to 1. It is growing at a rate of between 10 and 15 per cent each year. At this rate, expenditures on research may reach a figure of $10 billion by 1960 and in excess of $15 billion within the next ten years.

This research will result in new products and higher productivity. This greater productivity will contribute to the growth of the economy. An added factor will be the increased population, which is expected to increase from 170 to 190 million by 1965. Population increases will be accompanied by an increase in households, an increase in earning, an expansion of the middle-income group, and an increase in the funds available for spending on things other than the necessities of life.

Progress is linked to successful pioneering and utilization of new developments. The laboratory opens new scientific frontiers, but management must take the initiative to commercialize these results. Appraisals of the significance of developments places exacting demands on the engineers responsible. Further expansion of the economy will make technical acuteness increasingly important.

A Plan for Action

Leadership positions are achieved through research. By the time you read about a new development, someone else owns the patent on the device or process. Those who wish to occupy leadership positions can achieve these objectives by following patterns of action familiar in growth corporations. Where growth has been achieved,

1. Management has had a sincere desire to grow.
2. Effort has been expended on technical programs that reflect inherent growth potentials.
3. Organized programs have been established and put into action.

Success in pioneering new products reflects the highly individualistic efforts of scientists, engineers and executives, organized and channelled in potentially profitable directions. Programming calls for systematic planning, time to do the job, perspective, know-how, independent thinking, adequate facilities and personnel qualified for the job to be accomplished.

BIBLIOGRAPHY

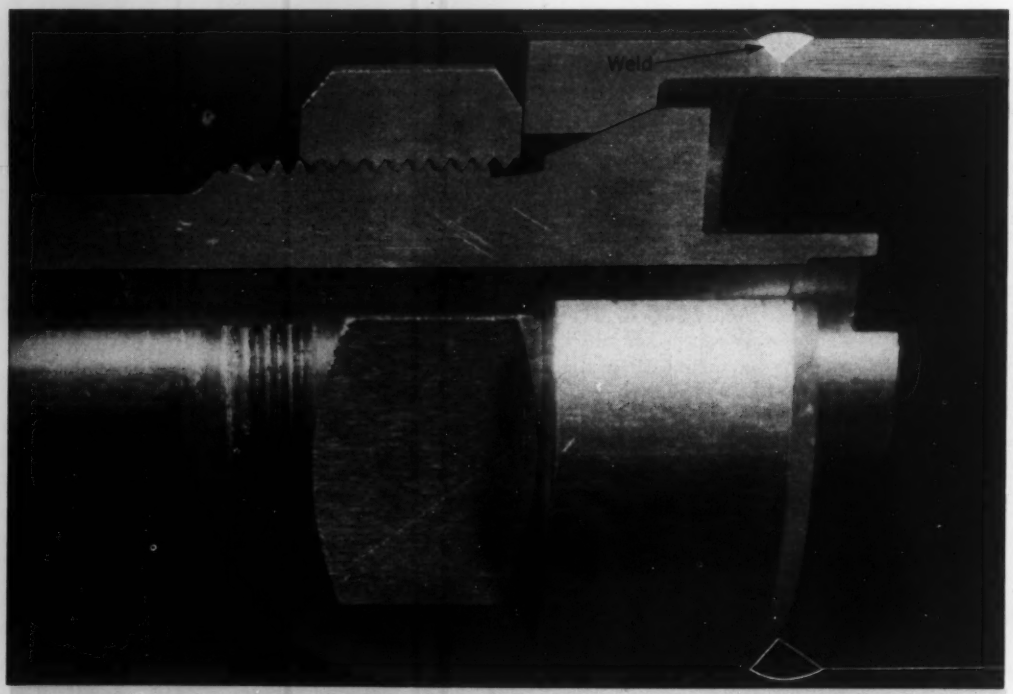
This article is the third in a co-ordinated group by Dr. Marvin on new-product development. The previous articles and the issues of MACHINE DESIGN in which they appeared are:

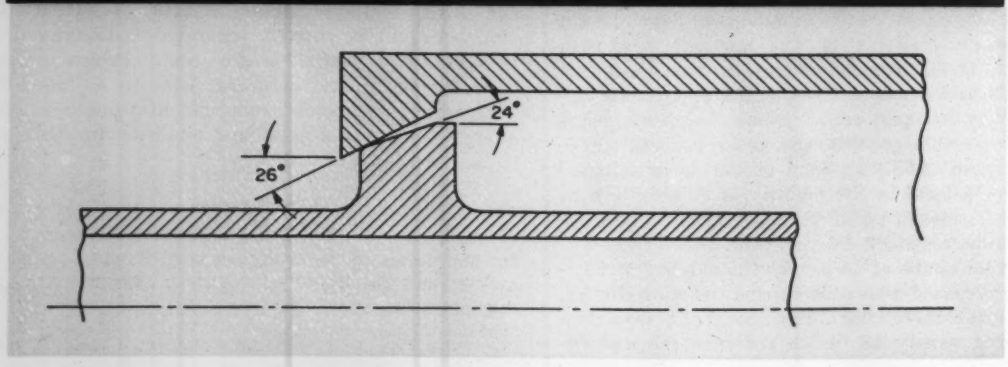
"Planning Product Strategy".....June 13, 1957
"Developing Ideas for New-Product Programs".....July 11, 1957

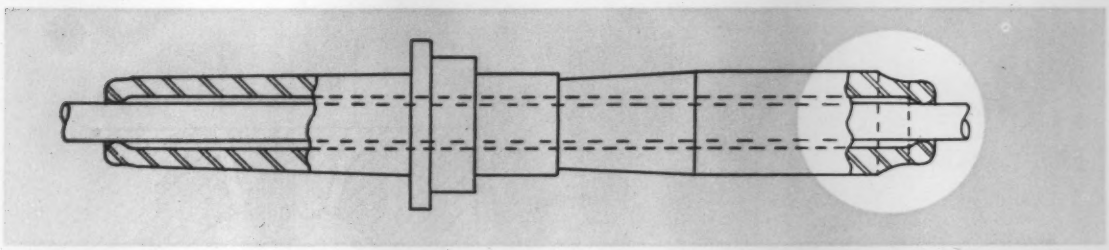
scanning the field for *ideas*

Conical sealing surfaces provide leakproof high-pressure joint for concentric tubes without additional sealing elements. Designed by Raymond Meyer of the Griscom-Russell Co., the seal design is suitable for a wide range of metals, pressures, temperatures and fluids. The wedging action is provided by using different angles for the male and female conical surfaces.

When the tube is placed inside the shell, the conical surfaces meet in line contact. As longitudinal force is applied to the inner cone by mechanical means or fluid pressure, the metal sealing surfaces yield, providing a squeezing and wiping effect that causes metal deformation. The area of deformation is proportional to the force applied, forming a leakproof seal at varying pressures.





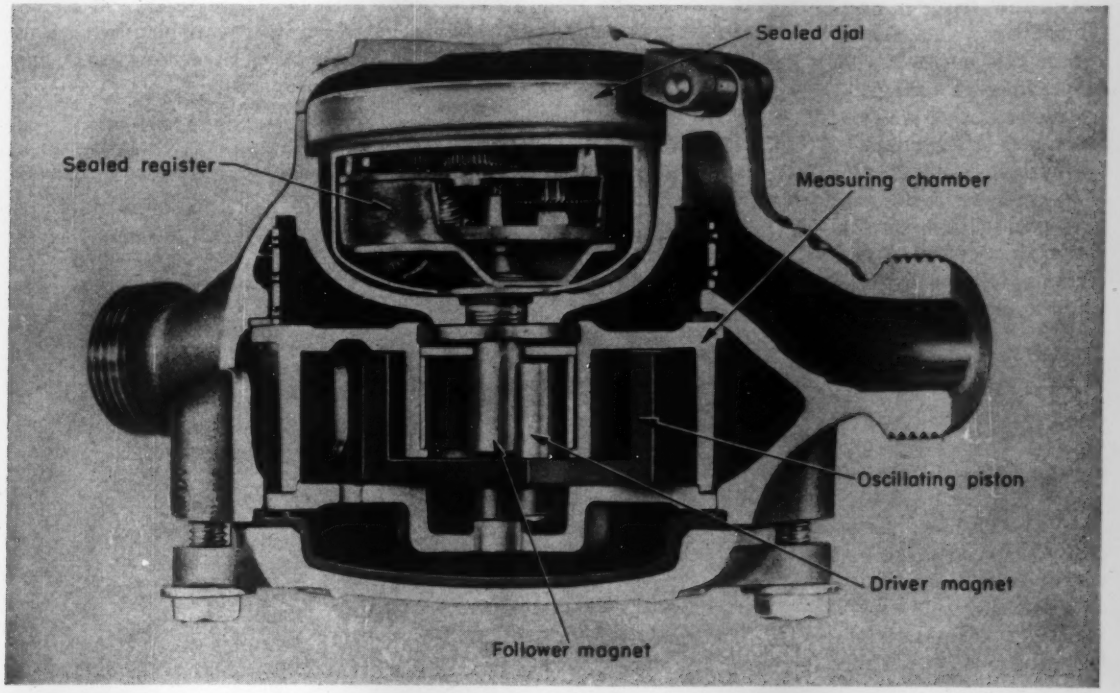


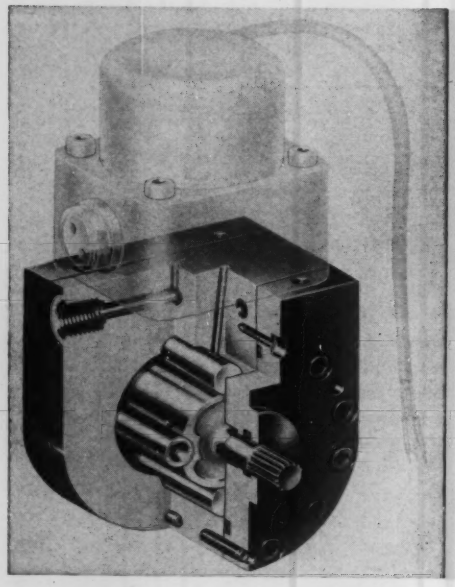
Swaged bearing surfaces avoid machining internal shaft clearance in miniature spindle. The design, reported by Superior Tube Co., is for a spindle of less than ¼-in. in overall length. Due to its tiny size, the use of conventional construction with bearings or bushings is impossible, and machining the internal relief is impractical.

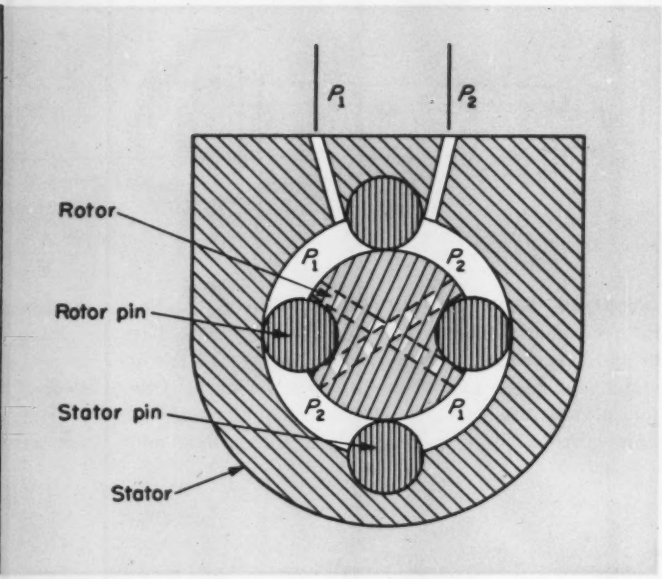
Each end of the precision-tubing spindle, which is used as a minute-hand spindle in a wrist watch, is swaged over a mandrel. Swaging provides a smooth bearing surface for the shaft to ±0.0005-in. without further machining or finishing.

Magnetic "transmission" provides minimum-friction drive between sealed chambers in a novel water meter designed by Rockwell Mfg. Co. The transmission consists of two magnets, one contained in the measuring chamber of the meter, the other in a well in the sealed register. The force between them effectively transmits motion from measuring chamber to register without connections and seals. Response to piston movement is rapid and accurate because the design permits use of light-duty instrument-type gearing in the register. The gearing requires only a portion of the power supplied by the magnetic transmission.

In this water-meter design, the measuring element is a balanced piston that oscillates within a circular measuring chamber, displacing a known amount of liquid with each oscillation. One of the permanent magnets is mounted vertically in a center post in the piston. The other is contained in a well in the sealed register casing. As the piston oscillates within the measuring chamber, the "driver" magnet in the center post drives the "follower" magnet inside the well. For each oscillation of the piston, the follower magnet is driven one complete revolution. The follower magnet drives a pinion shaft to transmit motion to the register.





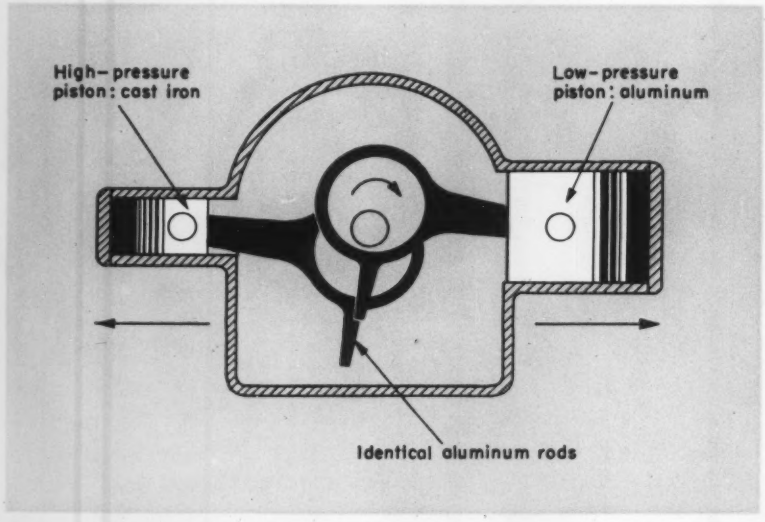


Cylindrical-pin vanes in rotary hydraulic actuator accommodate unsymmetrical operating loads and reduce static breakaway friction. Developed by Kelsey-Hayes Co. for hydraulic applications, a rotary actuator has four hardened vanes, two in the stator and two in the rotor, that are simply cylindrical pins. Semicylindrical grooves support each pin along its entire length, eliminating distortion due to bending forces.

Small radial expansion of the stator, caused by high fluid pressures in the active chambers, does not result in leakage past either the stationary or the moving pins. As load is applied, the leakage-inducing pressure differential forces the pins to seal along lines of contact with their seats and with the opposite walls. Because the pins are free to rotate, wear is distributed over a large cylindrical surface.

Balanced piston construction for air compressor with opposed cylinders of unequal diameter is achieved by using different piston materials. Developed by Ingersoll-Rand Co., the air compressor is designed with opposed cylinders in a horizontal plane. Reciprocating weights are balanced by employing aluminum for the larger piston and cast iron for the smaller. Both connecting rods are identical and of aluminum because of high speed (1700 rpm) of unit.

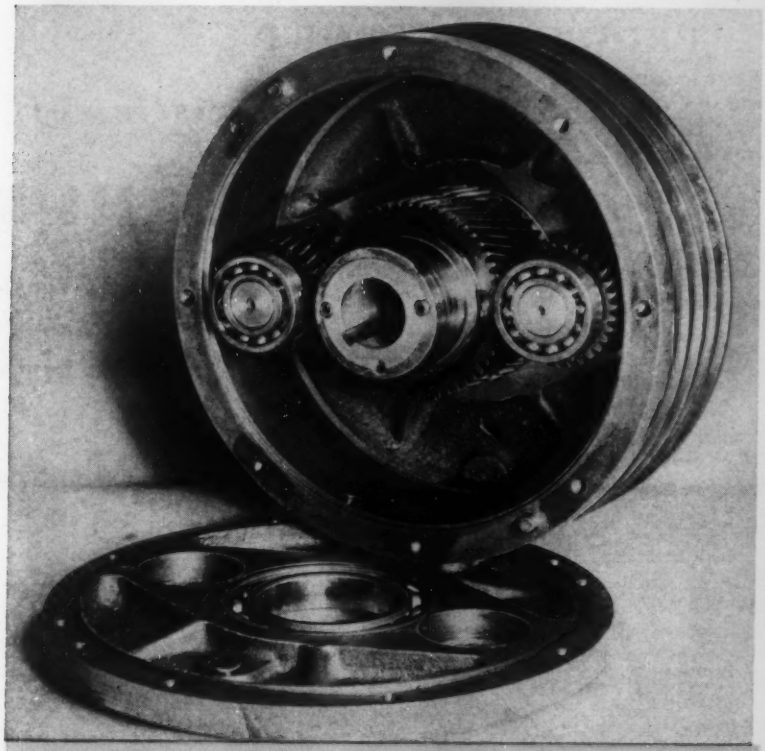
The high and low-pressure pistons move in opposite directions, reaching the end of their strokes simultaneously. The use of aluminum for the larger, low-pressure piston and cast iron for the high-pressure piston permits precise balance of all reciprocating elements. Reduction of vibration due to running balance of pistons and light weight of rods minimizes wear on moving parts and simplifies mounting of the unit to tank or support.

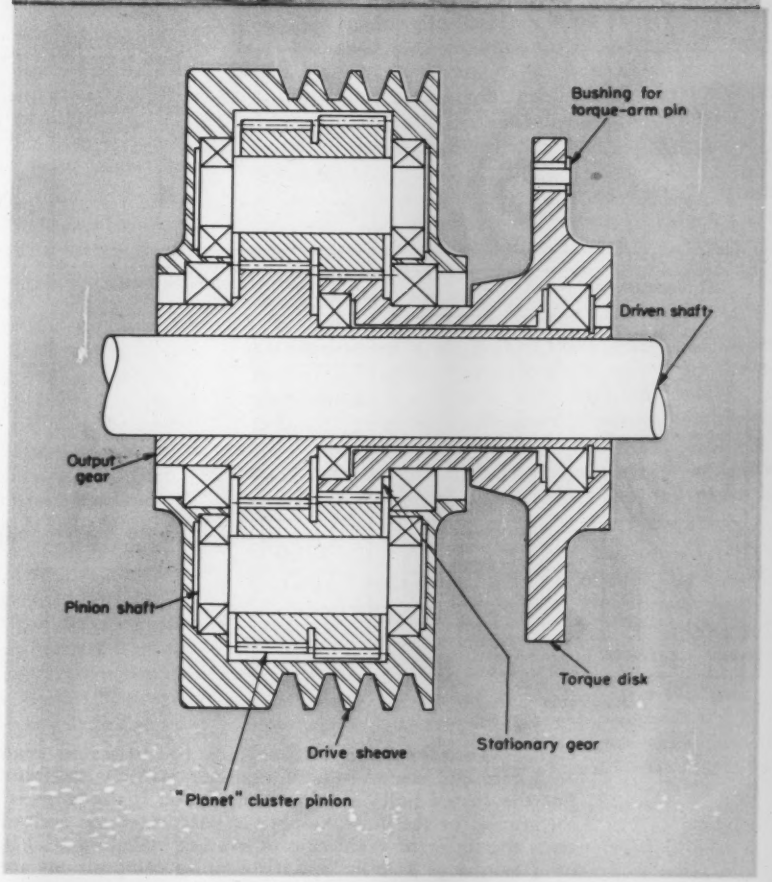


ideas

Built-in epicyclic gear train is used to develop high reduction ratios in a combination pulley-reducer unit. Mounted inside the V-belt drive sheave of the Hart reduction pulley, a compound epicyclic gear arrangement transmits power from sheave to output shaft at reduction ratios as high as 8000:1.

The reduction pulley consists essentially of a rotatable housing with V-belt grooves, a stationary gear, an output gear, and one or two "planet" cluster pinions. The output gear is mounted directly on the shaft to be driven; an extension on the stationary gear permits it to be anchored to prevent rotation. Speed reduction is obtained as the drive sheave rotates the larger pinion-cluster gears around the stationary gear and the smaller gears transmit torque to the output gear. Train ratio is determined by the relative number of teeth in the four gear elements. The inherent compactness of the epicyclic system achieves a large speed reduction in a small envelope.





PROGRESS REPORT

Application characteristics of

TITANIUM BOLTS

- **Torque-Tension Relationships**
- **Relaxation Properties**
- **Design Recommendations**

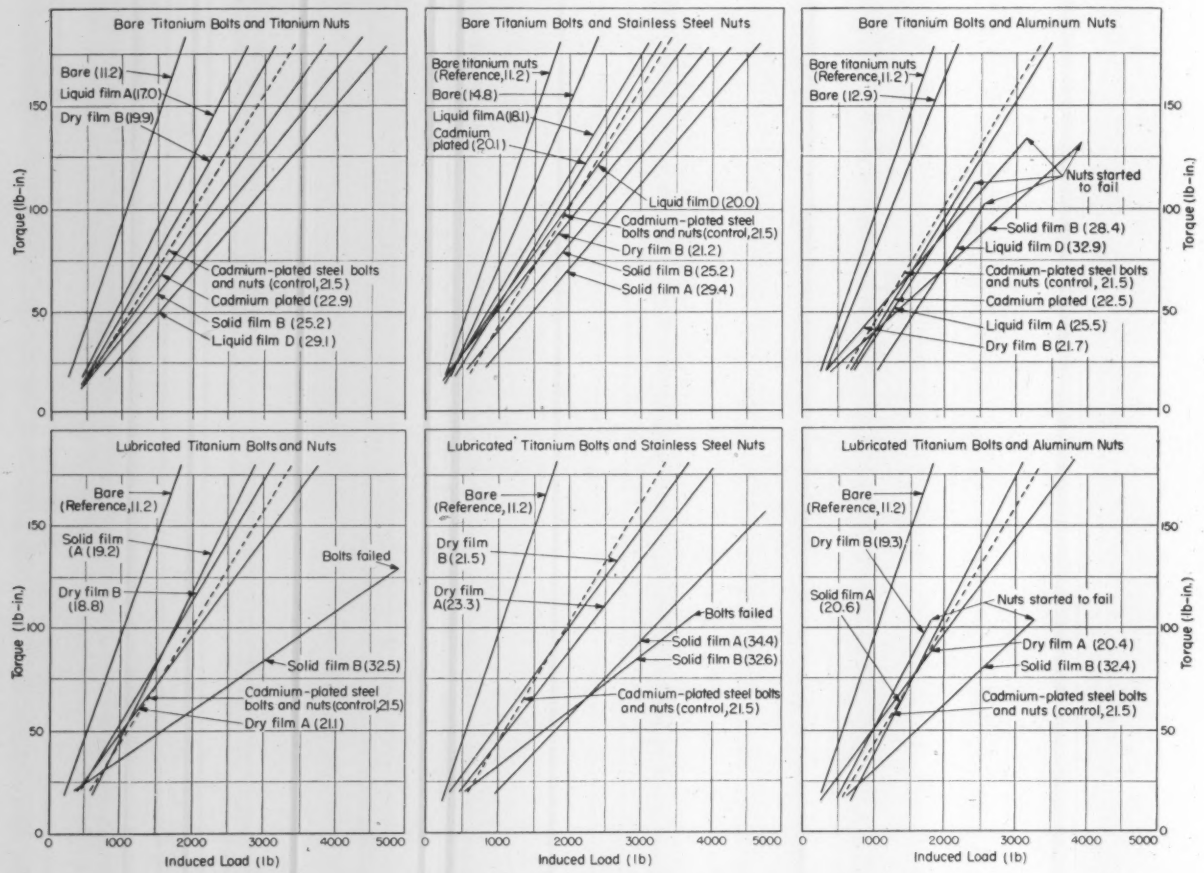


Fig. 1—Torque-tension relationships for bare and coated titanium bolts with bare and coated nuts of titanium, stainless steel and aluminum alloy. For the coated bolts, coating composition is the same as that indicated on the curves for the nuts. Number in parentheses on each of the curves represents the index of evaluation or average clamping load induced in the bolt by a torque of 1 lb-in. Specific coating compositions are given in Table 1.

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AS TITANIUM has become more readily available, its use in fasteners has appeared desirable from a strength-weight standpoint. Continued research in this direction has resulted in the development of titanium-alloy bolts with static and fatigue strength properties equivalent to those of comparable steel bolts.

However, experience gained in airframe applications has brought reports of two serious disadvantages with these fasteners:

1. Tendency of titanium threads to seize and gall, often preventing removal of nuts.
2. High degree of relaxation (loosening effect with time) of titanium-alloy bolts under operating loads.

To learn more about these unfavorable conditions and their possible remedies, a study was conducted recently of the operating characteristics of titanium-alloy bolts under load.

The primary objective of this investigation was to evaluate the influence of nut materials and thread lubricants on the seizing and galling characteristics of titanium threads as related to torque requirements of titanium-alloy bolts. A secondary objective was to establish the degree of relaxation of titanium-alloy bolts, as compared to that of similar steel bolts at identical working loads.

The steel bolts used as "control" elements were cadmium-plated aircraft bolts (MIL-B-6812) of medium-alloy steel having an approximate ultimate strength of 5400 lb, as compared to the 6130 lb average ultimate strength of the titanium-alloy bolts. For economy reasons, the investigation was limited to a study of the small and relatively inexpensive ¼-28 size titanium bolts. Results of this study are reported and analyzed in this article.

Test Conditions: Titanium bolts and nuts used for this evaluation were specially fabricated for the purpose, while stainless-steel and aluminum-alloy nuts were standard stock items. However, all bolts and nuts were machined to a uniform Class 3 fit, and only those items that successfully passed Go and No-Go gage inspection were used. Nuts and bolt heads were machined so that a circular washer effect was produced on the bearing surfaces.

A number of different coatings were used in combination with various nut materials to determine the combinations which would best alleviate the seizing and galling characteristics of the titanium bolt threads. These coatings fell into four categories: (1) metal plating, (2) liquid-film lubricants, (3) dry-film lubricants and (4) solid-film lubricants. Specific lubricant compositions are identified in Table 1. Dry-film lubricants are defined here as those which were applied locally in liquid form and baked on, while solid-film lubricants were those which involved proprietary manufacturing processes.

To determine the relation between torque and tensile load induced in the bolt, readings of load were taken for torque increments of 25 lb-in. up to a maximum of 175 lb-in. The latter torque value represents an average induced tensile stress of approximately 100,000 psi in a ¼-28 steel bolt with dry threads.

Variation in load produced by repeated torquing to a given value of 100 lb-in. was ascertained by reading the tensile load resulting from application of this torque a predetermined number of times. The 100 lb-in. torque value was used because it appears that a torque of between 85 and 100 lb-in. is generally used by airframe manufacturers for ¼-28 standard steel tension bolts and nuts with dry threads.

Relaxation tests were conducted on both titanium bolts and standard cadmium-plated steel aircraft bolts for comparison over a range from relatively low normal operating stresses to high stresses near yield strength.

It has been established that the light film of oil that remains on bolt threads after the manufacturing process has very little effect on thread friction. A significant reduction in friction is brought about by application of special high-pressure lubricants designed for the purpose. Reference here to bare or nonlubricated bolts and nuts means that special lubricants were not used. In

Table 1—Composition of Lubricant Coatings

Designation	Composition
Liquid film A	High concentration of molybdenum disulphide in a silicone carrier.
Liquid film B	Colloidal graphite carried in hydrocarbons.
Liquid film C	Dispersion of molybdenum disulphide.
Liquid film D	Aqueous tetrafluoroethylene dispersion.
Dry film A	Molybdenum disulphide combined with an epoxy type resin.
Dry film B	Colloidal graphite in an epoxy type resin.
Solid film A	Proprietary coating.
Solid film B	Proprietary coating.

*Opinions or assertions expressed in this article are those of the author and are not to be construed as official or reflecting the views of the Navy Department or the Naval Service at large. Illustrations appearing in this article have been adapted from official photographs, U. S. Navy.

all cases where a lubricant was being evaluated, the bolt threads were initially covered with it. For the repeated torque tests, however, no additional lubricant was added and none used under the bolt head.

Test Data: Torque-tension relationships developed by the various bolt, nut and coating combinations tested are depicted graphically in Fig. 1. The number in parentheses on each curve is an "index of evaluation" determined for that specific combination. Although this index is used as an arbitrary indication of the relative ability of the lubricant and nut material to alleviate the frictional characteristics of the bolt and nut arrangement, it actually represents the average clamping load induced in the bolt by a torque of 1 lb-in. The higher this numerical index, the better the combination for reducing galling and seizing.

The top three charts, Fig. 1, show torque-tension relationships for bare titanium bolts and titanium, stainless-steel and aluminum nuts—with the best coating of each type evaluated. The remaining three charts give results for coated titanium bolts with similar nut and coating combinations.

For the bolts and nuts evaluated, the relation between torque and tension was generally proportional at low loads. At high loads, considerable scatter occurred and the proportionality did not continue, primarily because of the bending of the threads. A disproportionately greater torque was required to produce increased stress. This limit of proportionality did not indicate that the bolts were approaching failure but merely illustrated the changing relationship at high loads. However, in plotting torque-tension curves, it was deemed advisable to treat them as straight-line functions for clarity and ease of presentation.

The more promising nut material and lubricant combinations underwent repetitive torque tests to determine variation in load produced by repeated torquing to 100 lb-in. The general loss of bolt tension was indicated by taking an overall average of the loss from the original induced load of all the combinations evaluated. In general, there is approximately a 30 per cent loss of bolt tension after five applications of torque. This loss increases until at the 25th application the bolt tension has been reduced to approximately 50 per cent of that obtained at the initial tightening.

The relaxation characteristics of the titanium and the steel bolts are shown in Table 2. This data indicates that titanium bolts have relaxation properties which are generally equal or superior to those of steel bolts. It is to be noted that relaxation of tension with time reaches a stable value with final bolt tension somewhat less than the initial preloading. The amount of relaxation, a phenomenon generally characteristic of all fasteners, depends on: surface conditions and crushing strength of plates clamped together; amount of bearing area in contact between head of bolt and plate; material of bolt; magnitude of original bolt tension; and time.

Autographic load-elongation diagrams for titanium and steel bolts are shown for comparison in Fig. 2. The elongation on the diagram represents the total bolt deformation as measured between the extreme ends of the bolt head and thread section.

Analysis of Results: Although a greater torque was required to induce a predetermined load in ¼-in. titanium-alloy bolt and nut fasteners than in similar steel bolts and nut combinations, there was little evidence to indicate that titanium threads seized at either low operating loads or at high loads approaching the yield strength, or after repeated torquing as many as 25 times.

Use of softer metallic coatings on nuts of different materials and the application of lubricants (including solid film on both bolts and nuts), improved the torque-tension relationship for ¼-in. titanium bolts. The improvement, as compared to the bare titanium bolt and bare titanium nut combination, ranged from slightly better for certain types of liquid-film lubricants to as high as three times as great for the special solid-film lubricants on both bolts and nuts.

Excluding the use of solid-film lubricants, which are believed to be impractical and unnecessary in this application for reasons discussed later, it has been found that for general all-purpose use the superior combinations are: (1) stainless-steel or high-strength aluminum-alloy nuts (coated with

Table 2—Bolt Relaxation Test Data*

Bolt Material	Initial Conditions		Recorded Load (lb)						
	Load (lb)	Stress (psi)	1 hr	4 hr	24 hr	48 hr	72 hr	96 hr	168 hr
Titanium	2000	52,500	2000	1990	S	S	S	S	S
Steel	2000	52,500	1995	1990	1970	S	S	S	S
Titanium	2500	69,060	2485	2475	S	S	S	S	S
Steel	2500	69,060	2480	2470	S	S	S	S	S
Titanium	3000	82,870	2970	2965	2960	2950	S	S	S
Steel	3000	82,870	2965	2960	2950	S	S	S	S
Titanium	3500	96,680	3470	3465	3460	3450	S	S	S
Steel	3500	96,680	3450	3450	3435	3415	S	S	S
Titanium	4000	110,500	3945	3935	3930	S	S	S	S
Steel	4000	110,500	3935	3920	3900	3885	S	S	S
Titanium	4500	124,300	4440	4435	4425	4410	4400	4390	S
Steel	4500	124,300	4365	4350	4325	4320	S	S	S

*S = Point at which relaxation reached a stable point. All bolts were ¼-28. For titanium bolts, ultimate strength = 6100 lb, proportional limit = 5200 lb. For steel bolts, ultimate strength = 5350 lb, proportional limit = 4500 lb.

either silver or cadmium), or (2) stainless-steel or aluminum-alloy nuts lubricated with some form of molybdenum disulphide or tetrafluoroethylene. These combinations of nut materials, metallic coatings and/or lubricants also have excellent torque-tension relationships which do not show any marked deterioration with repeated torquing.

It has been shown that the relationship between torque and tension is generally proportional at low loads, but this proportionality does not continue at high loads due to the bending of the threads and some other factors which cause an increase in the frictional properties.

The relaxation tests have shown that the resistance to relaxation of titanium bolts and steel bolts are about equal, except at extremely high loads where this property of titanium bolts is superior, due to the greater yield strength.

The results of the evaluation of the torque tightening tests using titanium nuts in combination with various lubricants have been included here but are purely academic in nature, since it is the consensus of opinion among airframe manufacturers that the wholesale use of titanium nuts lies in the distant future. The desire of the aircraft industry to save weight is somewhat tempered by the excessive cost of titanium nuts due to complex machining operations and excessive scrap loss. If titanium, instead of steel, nuts are used, it is estimated that it would cost a minimum of $200 per pound of weight saved. On the other hand, the use of high-strength aluminum-alloy nuts, capable of meeting the same tensile strength requirements as either the steel or titanium nuts they would replace, would make the cost of weight saving only $0.60 per pound. Realistically, it would seem that wholesale use of titanium nuts will only be possible when a greater availability of suitable titanium alloys, better production methods, and an economical scrap-recovery process could reduce the cost to practical limits.

Similarly, test data involving baked coatings and so-called permanent-type solid-film lubricants on titanium bolts have also been included here for comparison purposes. But here again, practical considerations dictate that all lubricating techniques which require additional or special processes for lubricating titanium bolt threads be discarded for the present. It is believed that the use of solid-film type lubricant on the titanium bolts is not warranted, since the beneficial effects do not compensate for the additional cost and, in some cases, for the lack of interchangeability resulting from some special processes which require that the bolts and nuts must be reduced in dimensions to allow for the thickness of the film.

The cadmium plating on the nuts was made comparatively thin so that the underlying steel or aluminum carried the load and the low shear strength of the cadmium reduced the frictional characteristics. The reported coefficient of friction of cadmium when used as a thin film is approximately 0.1, whereas the reported coefficient of friction of clean titanium on clean titanium is approximately 0.5. It is well to note that a decrease of coefficient of friction because of smoother finish, plating, or lubrication may produce a dangerously high stress in the bolt as a result of an otherwise safe torque. This did occur during this investigation when torquing titanium bolts and nuts of different materials that were coated with permanent type solid-film lubrication. Similarly, the use of lubricated standard aluminum aircraft nuts could result in failure of the nut threads while torquing at higher loads, as was evident while conducting the torque-tension tests. However, high-strength aluminum-alloy nut material, which is now available, is capable of meeting the same tensile requirements as steel or titanium nuts and would overcome this condition.

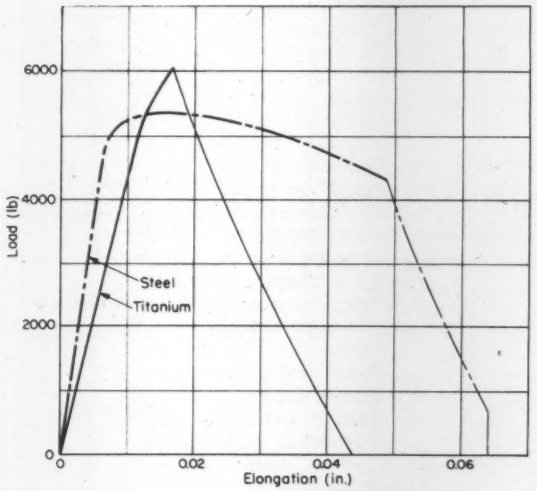


Fig. 2—Load-elongation diagrams for titanium and steel bolts.

Design Recommendations: For reduction of seizing and galling characteristics, it is recommended that titanium bolts be used with: (1) nonlubricated silver or cadmium-plated stainless-steel nuts, (2) nonlubricated silver or cadmium-plated high-strength aluminum-alloy nuts, or (3) unplated stainless-steel or high-strength aluminum-alloy nuts which are lubricated with either molybdenum disulphide in an epoxy-type resin or with an aqueous dispersion of tetrafluoroethylene.

Titanium bolts may be safely substituted for and replace steel bolts, all other considerations being equal, in any bolting application where a minimum of bolt relaxation is essential.

They Say . . .

The overall rule which will produce the best (production) results is to develop a feeling of empathy for the processing engineer. Put yourself in his place and try to design for machining.—R. D. HALVERSTADT, *General Electric Co.*

Quantitative design of

SERVO SYSTEMS

by frequency-response methods

Part 3—Gain-Phase Relationships

By J. M. Nightingale
Manchester, England

THERE are close relations, as previously stated, between the gain and phase characteristics of most practical components.[1-15] The exact nature of these relationships will now be shown and some practical implications will be briefly discussed. Most of the formulas given were developed by Bode,[16] and in their original context applied to electronic feedback amplifiers. Nevertheless, they are of considerable importance in the servo field and contribute much to general background of design by frequency-response methods.

The relations given here hold only for minimum-phase systems. The meaning of this term is as follows.

One way of characterizing a transfer function is by means of its poles and zeros. Thus,

$$Y(s) = \frac{H(s - z_1)(s - z_2)\ldots}{(s - p_1)(s - p_2)\ldots} \qquad (8)$$

If $Y(s)$ characterizes a stable system, then all the poles p_1, p_2, . . . must lie in the left-half of the s plane. The minimum phase condition further restricts $Y(s)$ so that all the zeros z_1, z_2, . . . shall also lie in the left-half plane. For example, $(1 + 2s)/(1 + 3s)$ is minimum phase, while $(1 - 2s)/(1 + 3s)$ is nonminimum phase. Ordinarily, most practical servo elements have transfer functions which satisfy the minimum-phase condition.

One important property of such elements is that

[1]References are tabulated at end of article.

Nomenclature

$A(\omega)$	= Loop gain in decibels
$A_1(\omega), \ldots$	= Gains in decibels
a	= Constant
e	= Error
H	= Constant
K	= Scalar gain constant
k	= Constant
$M(\omega)$	= Overall amplitude ratio
$N(\omega)$	= Loop amplitude ratio
$N_1(\omega), \ldots$	= Amplitude ratios
n	= Constant
$p_1, \ldots$	= Poles
r	= Order of servo
s	= Laplace operator
T	= Time constant
$T_1, \ldots$	= Time constants
u	= Nondimensional frequency variable
x	= Nondimensional frequency
$Y(s)$	= Transfer function
$Y_o(s)$	= Loop transfer function
$Y_o(j\omega)$	= Loop harmonic response function
$Y(s)$	= Transfer function
$z_1, \ldots$	= Zeros
$\psi(\omega)$	= Loop phase angle
$\psi_1(\omega)$	= Phase angles
θ_o, θ_i	= Output and input
ω	= Frequency variable
$\phi(\omega)$	= Overall phase
τ	= Time delay
ζ	= Damping ratio

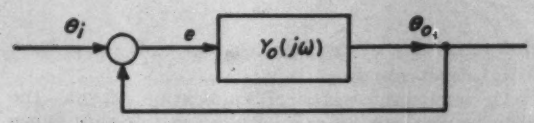
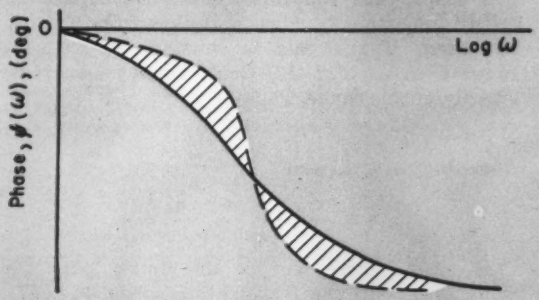
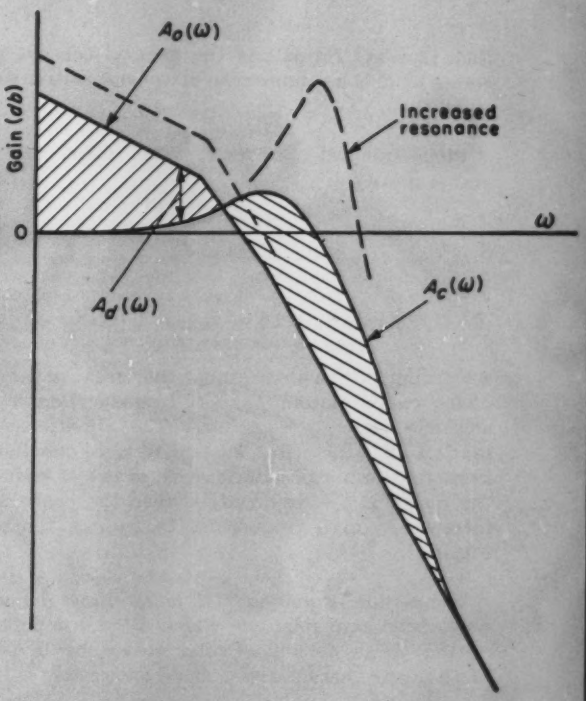


Fig. 11—Block diagram of single-loop control system.

Fig. 12—Right—Diagram showing significance of gain integral theorem applied to feedback system. The two shaded areas must be equal. Attempts to increase K to improve bandwidth result in increased resonance at higher frequencies.

Fig. 13—Below—Diagram showing significance of phase integral theorem. If the gain is fixed at high and low frequencies, then attempting to reduce phase lag at low frequencies results in increased lags at high frequencies.





for a given phase characteristic the minimum-phase transfer function will yield the smallest possible change in phase between zero and infinite frequency. This property leads to the name given to such elements.

Bode and others have developed a number of theorems relating the gain and phase of minimum-phase elements. The more important of these from a servo point of view will now be stated together with some practical implications.

As before, gain and phase are defined as

$$\left.\begin{aligned} A(\omega) &= 20 \log_{10} |Y(j\omega)| \; db \\ \psi(\omega) &= \arg Y(j\omega) \end{aligned}\right\} \tag{9}$$

Most of the following formulas are normally defined in terms of gain as the natural logarithm of $|Y(j\omega)|$ but in order to maintain continuity with earlier parts of this article the decibel definition is used, rather than natural logarithms, and the factor $\lambda = 0.115$ is introduced.

Gain-Integral Theorem: This theorem is stated as

$$\int_0^\infty (A - A_\infty) d\omega = -\frac{\pi}{2\lambda} \gamma \tag{10}$$

where

$$A = A(\omega); \; A_\infty = [A(\omega)]_{\omega \to \infty}; \; \gamma = [\omega \psi(\omega)]_{\omega \to \infty}$$

Application of the theorem to the closed loop system shown in Fig. 11 may now be considered. The overall response function is

$$Y_c(j\omega) = \frac{Y_o(j\omega)}{1 + Y_o(j\omega)} \tag{11}$$

Any practical system will contain lags so that at very high frequencies both $Y_c(j\omega)$ and $Y_o(j\omega)$ behave as $k/(j\omega)^n$ where k is a constant and n a positive integer. Thus plots of the gain and phase of Y_o and Y_c will merge together at high frequencies, Fig. 12. The difference between A_c and A_o, that is A_d, is sometimes called the deviation ratio. Obviously,

$$A_d = -20 \log_{10} |1 + Y_o(j\omega)| \tag{12}$$

If A_d is substituted for A in Equation 10, it follows, since Y_o and Y_c are asymptotically the same at high frequencies, that A_∞ and γ are both zero in this case. Therefore,

$$20 \int_0^\infty \log_{10} |1 + Y(j\omega)| \, d\omega = \int_0^\infty A_d \, d\omega = 0 \tag{13}$$

Thus the two shaded areas of Fig. 12 must be equal, if ω is plotted on an arithmetical rather than logarithmic scale. The most serious implication is that, if effort is made to increase bandwidth and low-frequency gain by increasing K, there must be an increase of the resonant tendencies of the overall gain curve as shown dotted in

Fig. 12. This formalizes the general concept that choice of K is a compromise between sensitivity and stability.

Phase-Integral Theorem: The form of this theorem is

$$\int_{-\infty}^{\infty} \psi \, du = \frac{\lambda\pi}{2} (A_\infty - A_1) \qquad (14)$$

where

$$\psi = \psi(u); \; A_1 = [A(\omega)]_{\omega=0}; \; u = \log_e (\omega/\omega_o); \; \omega_o = \text{a reference frequency}$$

According to this theorem, the area under the phase curve plotted against frequency on a logarithmic scale is constant. The significance is that, if in a practical system it were possible to keep the gain characteristic fixed while reducing the phase at low frequencies, then the phase must increase at high frequencies to balance the area, Fig. 13.

Phase-Gain Equation: Of more direct value in servo work are relations which allow computation of the phase at a particular frequency in terms of the gain characteristic. Bode shows that

$$\psi_c = \frac{2\omega_c \lambda}{\pi} \int_0^{\infty} \frac{A - A_c}{\omega^2 - \omega_c^2} \, d\omega \qquad (15)$$

A more useful form can be obtained with the transformation $u = \log_e(\omega/\omega_c)$; thus,

$$\psi_c = \frac{\lambda}{\pi} \int_{-\infty}^{\infty} \frac{dA}{du} \log_e \coth \frac{|u|}{2} \, du \qquad (16)$$

where $A_c = A(\omega_c)$ and $\psi_c = \psi(\omega_c)$.

It will be seen that the phase at some particular frequency ω_c depends on the slope of the gain dA/du. $\text{Log}_e \coth(|u|/2)$ is a weighting function which is plotted in Fig. 14. Obviously most weight is given to the slope of gain near ω_c and the gain characteristics at frequencies remote from ω_c have little effect on ψ_c.

An important practical application is that the phase curve can be computed from the gain curve if this is known, probably with greater accuracy than phase could be actually measured. Reference 16 includes some practical aids to computation.

The general implication of Equation 16 is that large changes in gain slope are always accompanied by rapid changes in phase and vice versa. See, for example, Fig. 15. Thus minimum-phase networks are unlikely to have gain-phase characteristics indicated by the Nyquist plot of Fig. 16. Here phase shifts occur without much change in gain slope, thus violating the implied dependency.

Two important conclusions follow from Equation 16: First, if the gain is constant in frequency range 0 to ω_b, Fig. 17, then the phase increases linearly in this range. Thus

$$\psi_c = \tau\omega_c \qquad (17)$$

where $0 < \omega_c < \omega_b$ and

$$\tau \approx \frac{2\lambda}{\pi} \int_{\omega_b}^{\infty} \frac{A - A_c}{\omega^2} \, d\omega$$

This means there will be an almost pure time delay of τ with the transient response, Fig. 17.

Second, a phase angle of $-n\pi/2$ is associated with a gain slope of $-20n$ db per decade. Both these results are borne out by the asymptotic approximation to a simple lag, Fig. 2 (Part 1), which is a combination of the two cases mentioned.

Other important gain-phase relations are shown in Fig. 18. As the designer becomes familiar with the general related forms of such gain and phase curves, he will almost instinctively know the type of compensation to be applied in a specific case.

Gain-Phase Equation: Obtaining gain characteristic from the phase curve is possible, but is not

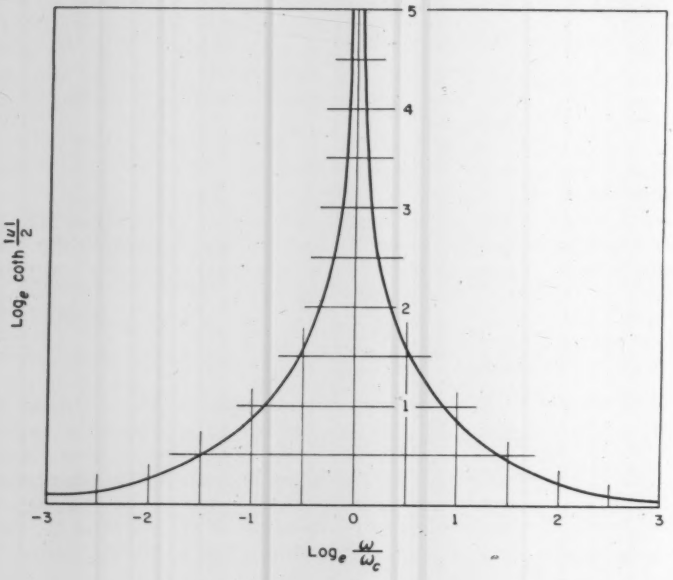


Fig. 14—Plot of weighting function $\log_e \coth (|u|/2)$. Note that only contributions of gain slope near frequency ω_c are weighted appreciably.

of so much importance because of the difficulty of obtaining accurate phase measurements, particularly at high frequencies. One form of the required formula is

$$A_c - A_1 = \frac{\omega_c}{\lambda\pi}\int_0^\infty \frac{d\left(\frac{\psi}{\omega}\right)}{d\omega}\log_e\left|\frac{\omega+\omega_c}{\omega-\omega_c}\right| d\omega \quad \ldots\ldots (18)$$

However, this relation could be used to find the resulting gain changes if the phase curve were reshaped by a phase advance network, for example.

References

This article is the sixteenth in a co-ordinated group by J. M. Nightingale on servo systems. The previous articles and the issues of MACHINE DESIGN in which they appeared are:

1. "Automatic Control Systems" .....May 17, 1956
2. "Servo Mathematics" .....June 28, 1956
3. "Evaluating Servo System Performance—Part 1"..July 26, 1956
4. "Evaluating Servo System Performance—Part 2"..Aug. 9, 1956
5. "Analyzing Servo Systems" .....Nov. 1, 1956
6. "Hydraulic Servo Components—Part 1" .....Nov. 29, 1956
7. "Hydraulic Servo Components—Part 2" .....Dec. 13, 1956
8. "Hydraulic Servo Components—Part 3" .....Dec. 27, 1956
9. "Hydraulic Servos—Part 1" .....Feb. 21, 1957
10. "Hydraulic Servos—Part 2" .....Mar. 7, 1957
11. "Hydraulic Servos—Part 3" .....Mar. 21, 1957
12. "Improving Servo System Performance—Part 1"..May 30, 1957
13. "Improving Servo System Performance—Part 2"..June 13, 1957
14. "Quantitative Design of Servo Systems—Part 1"..July 11, 1957
15. "Quantitative Design of Servo Systems—Part 2"..July 25, 1957

Another reference mentioned in the current article is:

16. H. Bode—*Network Analysis and Feedback Amplifier Design*, D. Van Nostrand Co. Inc., New York, 1945.

Reprints

Articles listed above by J. M. Nightingale are now available in reprint form. Articles 1 to 5 are contained in Volume 1 (32 pages) and articles 6 to 11 in Volume 2 (32 pages) of "Hydraulic Servo Fundamentals." The volumes are available at $1.00 each from Reader Service Dept., MACHINE DESIGN, Penton Bldg., Cleveland 13, O.

Fig. 15—Gain-phase relation. It implies that large changes in gain slope must produce rapid changes in phase and vice versa.

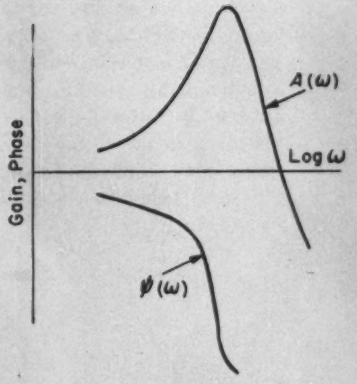


Fig. 16—Diagram showing locus undergoing large phase shifts with only small changes in gain slope. Hence it is unlikely that such a curve could be realized by a physical minimum-phase network.

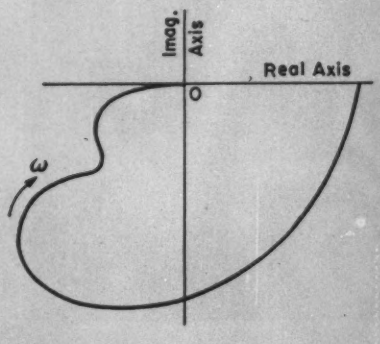


Fig. 17—At *a*, gain characteristic is flat up to ω_b. This produces linear phase in this region. Any system approximating this characteristic will have a time delay τ associated with its transient response, *b*.

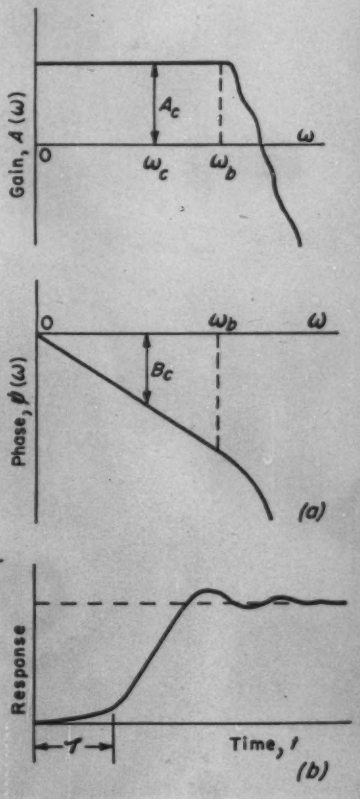
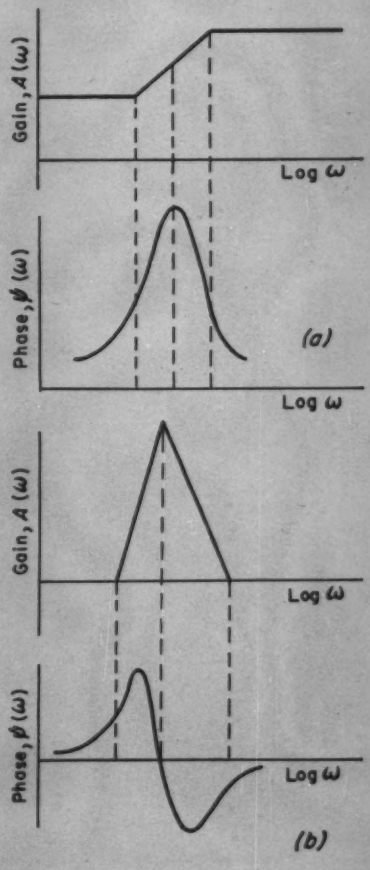
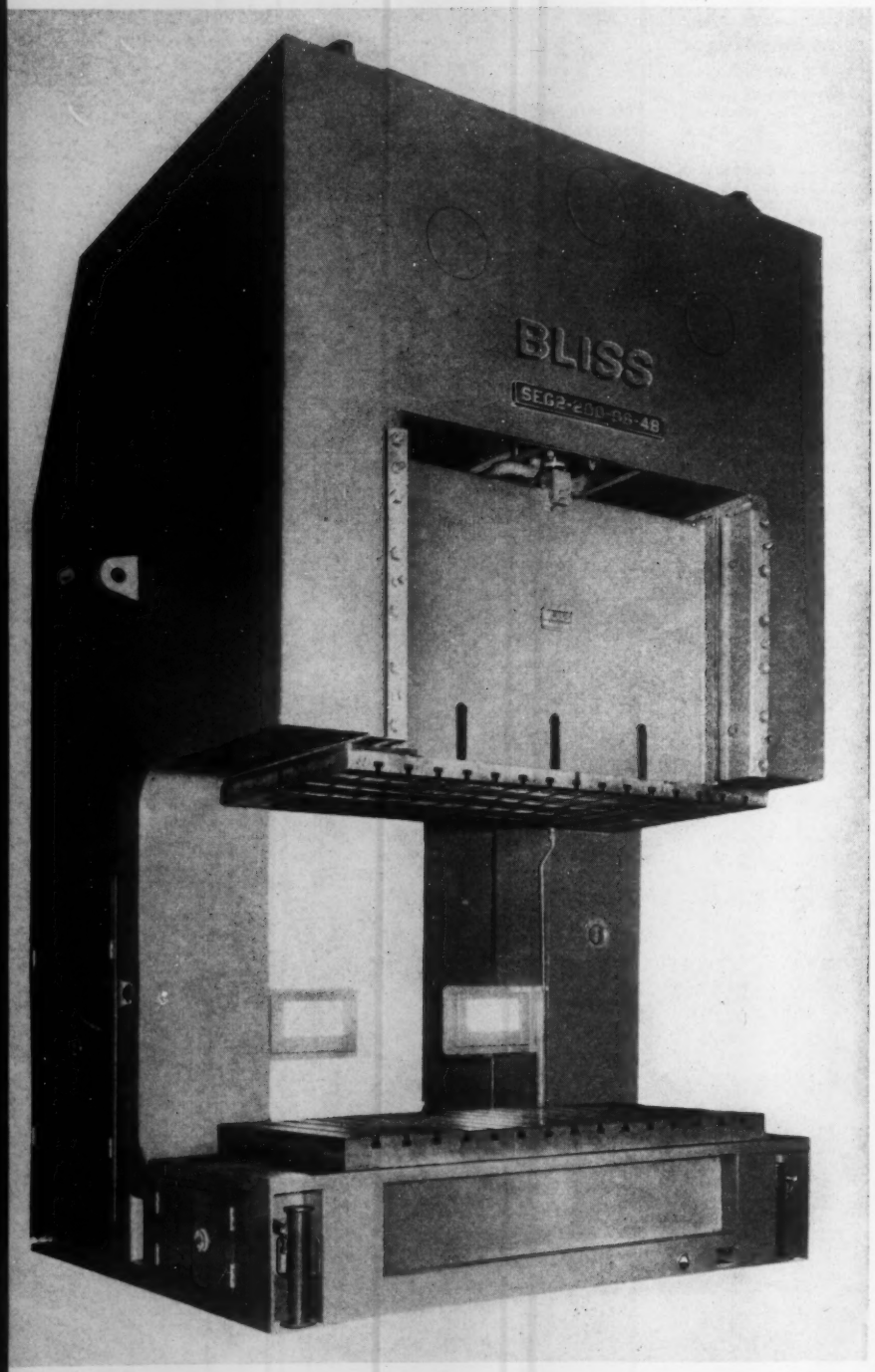


Fig. 18 — Illustrations of gain-phase relations. At *a*, gain characteristics associated with phase increase in given frequency band is shown while, at *b*, phase associated with bandpass gain characteristic is shown.



One-Piece Press-Frame Construction



A new eccentric - driven, single-action press, which has a 96 by 48-in. bolster plate, is constructed with a one-piece frame. Custom-built by the E. W. Bliss Co., this 200-ton gap-frame press provides a large, unobstructed die area. It was designed for piercing automobile fenders.

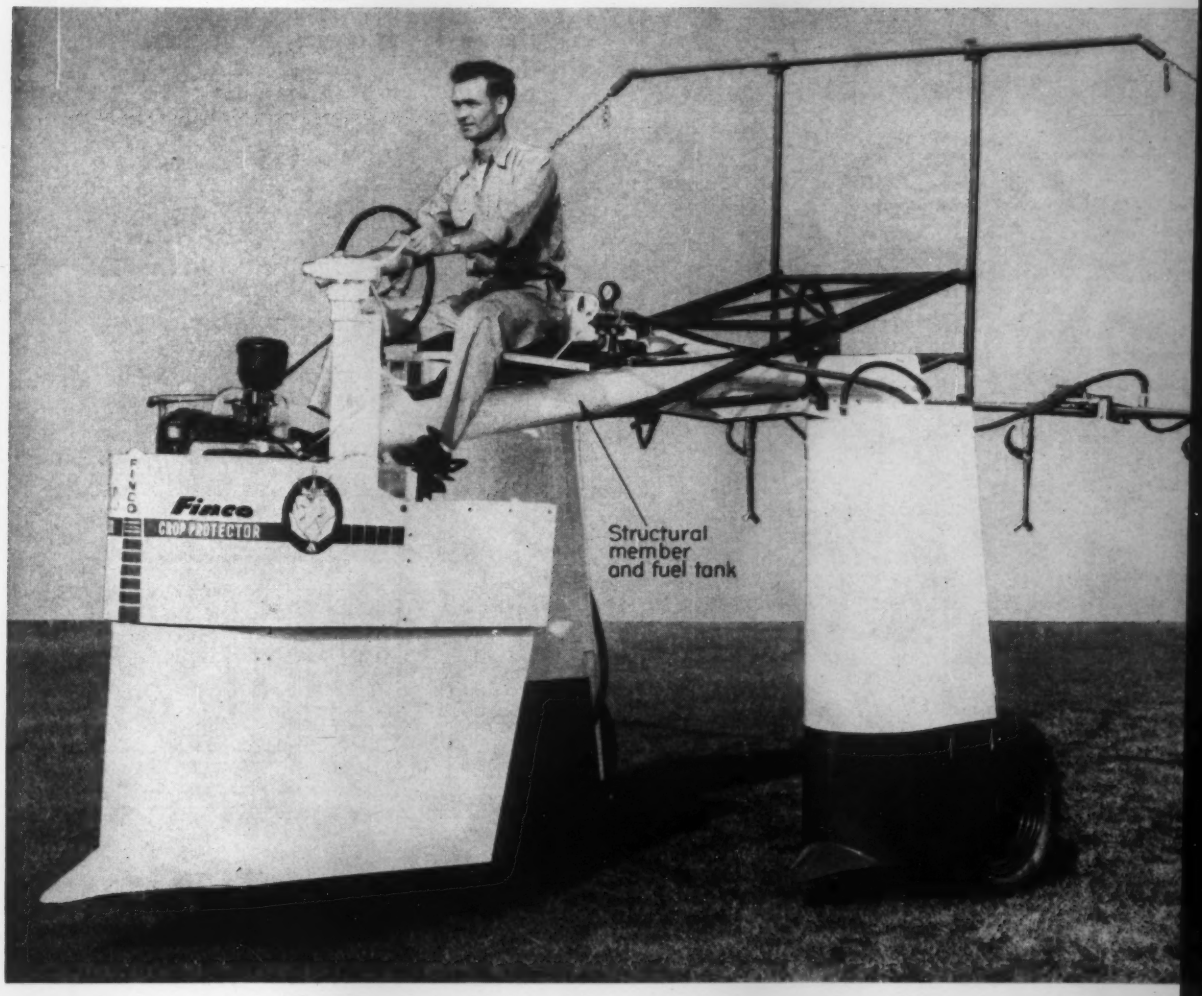
Other features include pneumatic friction clutch and brake, slide arranged for three - bar knockout, electric pushbutton control, stroke indicator, die cushions, die lights, safety jacks and a special rotary synchronizing switch. An automatic filtered-oil lubrication system for the entire press, including ram gibs and cushions, is also provided.

Large Metal Tubing Used as Combination Chassis and Fuel Tank

In a high-clearance spraying machine designed by Finco Inc., a 6-in. OD welded-steel tube with 0.180-in. wall is used as the center structural member. This same piece of tubing also serves as the fuel tank, holding a supply of gasoline sufficient to keep the engine operating all day.

The sprayer, with nozzles adjustable for heights from 10 in. to more than 10 ft above the ground, utilizes tubing throughout its design. A heavy-wall, 4¼-in. OD welded-steel tube is used as a front-axle hub. A 3⅛-in. OD welded tube with a 3/16-in. wall covers the steering column. A 5-in. OD welded tube with 0.247-in. wall is used on the rear legs, which must telescope over a structural member on the main center frame. Also, 2-in. OD welded tubing with 5/32-in. wall is used for constructing pivot members of the parallelogram assembly that holds the sprayer boom.

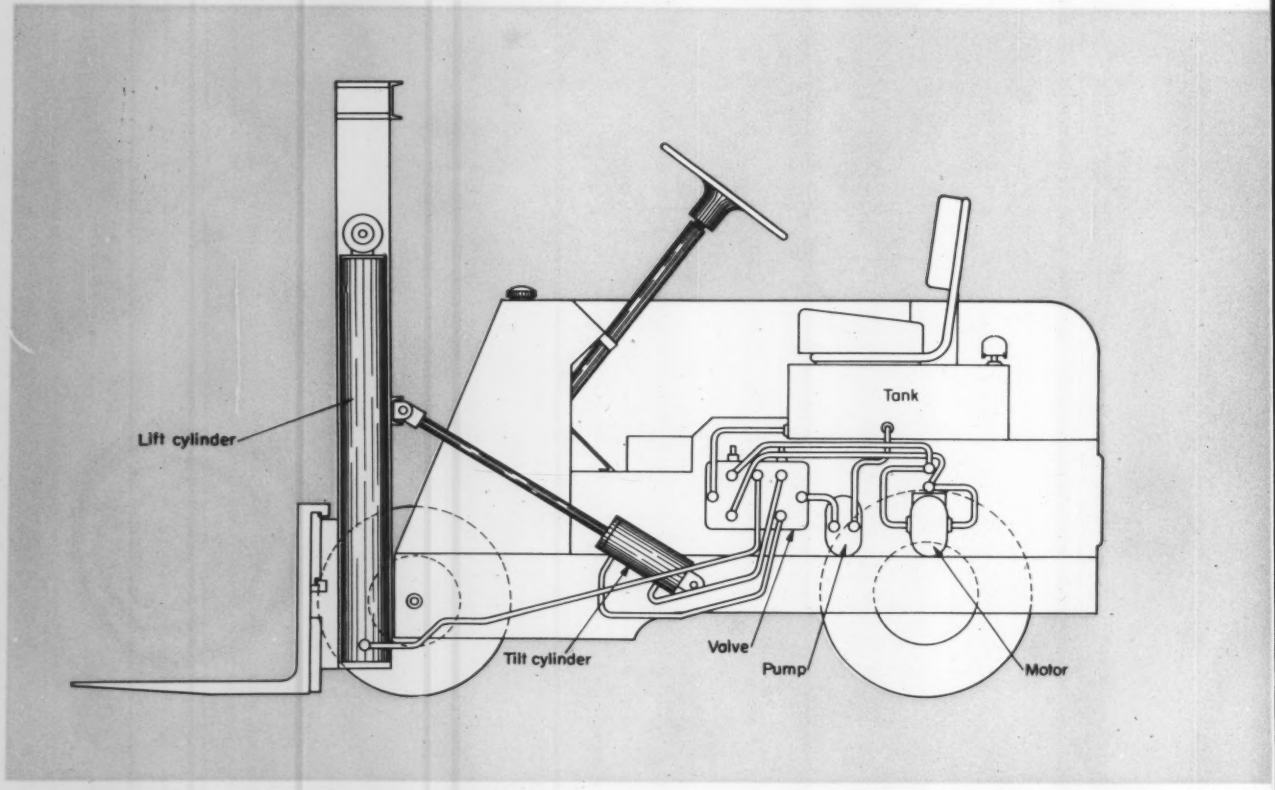
Data, courtesy Formed Steel Tube Institute.



All-Hydraulic Drive and

A new three-wheeled fork truck, designed and built by the Pettibone Mulliken Corp., employs an all-hydraulic vehicle drive and fork lift and tilt control system. The machine can be propelled in either direction at speeds up to 11 mph.

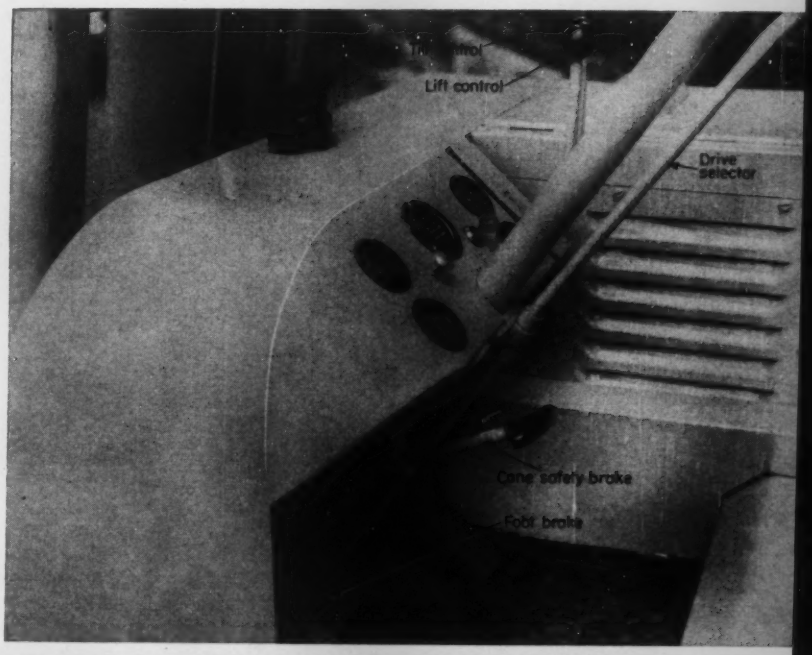
Hydraulic drive and control power is provided by a single, gear type hydraulic pump that is directly connected to a 50-hp Willys engine. Oil from the pump is forced into the valving chamber and circulatory system. The manually controlled valves are full-feathering, spool type designs. Drive, lift and tilt operations can be controlled individually or collectively.



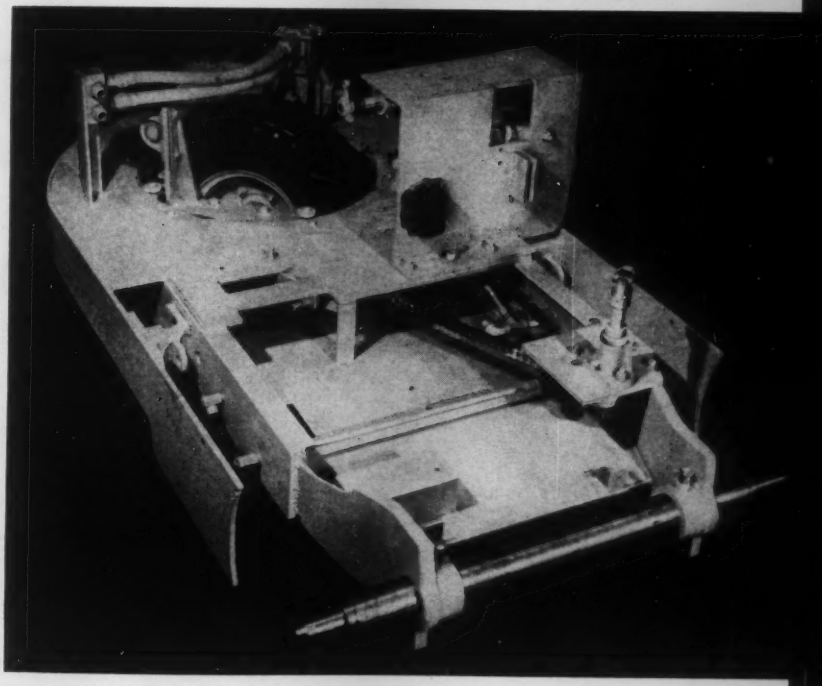
Control System

"Human - engineered" cockpit design has all instruments in easy view, and all drive and fork controls positioned for ease of operation. A drive-selector position gage on dashboard indicates reverse, neutral or forward.

Positive, all-hydraulic braking is accomplished by either placing drive selector lever in neutral or by depressing the foot brake. Both of these braking actions are achieved by blocking fluid flow. In addition, the truck is designed with a mechanical cane type safety brake, and a "dead-man" brake is available as an accessory.

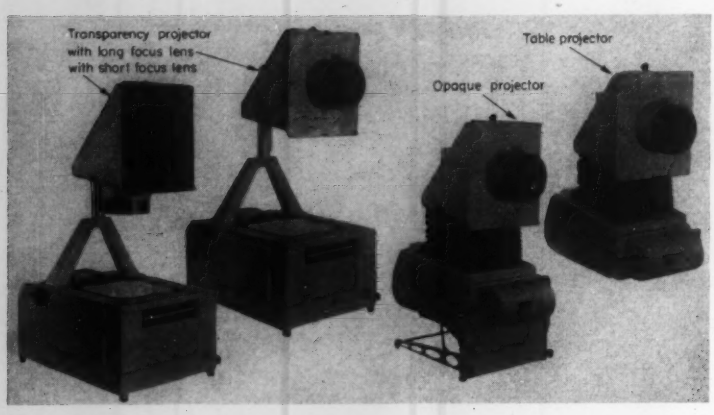


Propelling and steering of truck is accomplished through a single, 21-in. diameter rear wheel. Power is applied to the wheel, through a roller-chain speed reduction drive, by a hydraulic motor which is mounted directly on the wheel-frame assembly. Hydraulic fluid is pumped to the motor through flexible tubing, permitting the motor to turn with the wheel through a 180-deg arc.



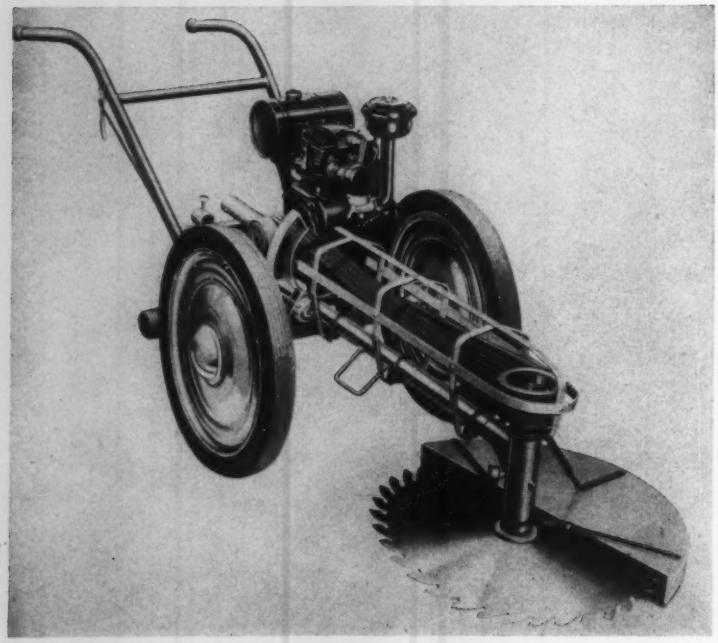
Multiple-Function Projector Design

The Transpaque II is claimed to be the first projector to use a single projection head and lens for four methods of projection: for opaque, transparency, table and rear. In addition to projecting 10 by 10-in. transparencies and 11 by 11-in. opaques, the instrument can be set directly on large surfaces for projection of 11 by 11-in. areas.



Designed by Projection Optics Co., the unit has a complete selection of lenses in focal lengths extending over a range from 4 to 40 in., enabling the operator to obtain a projected image of the desired size at any projection distance.

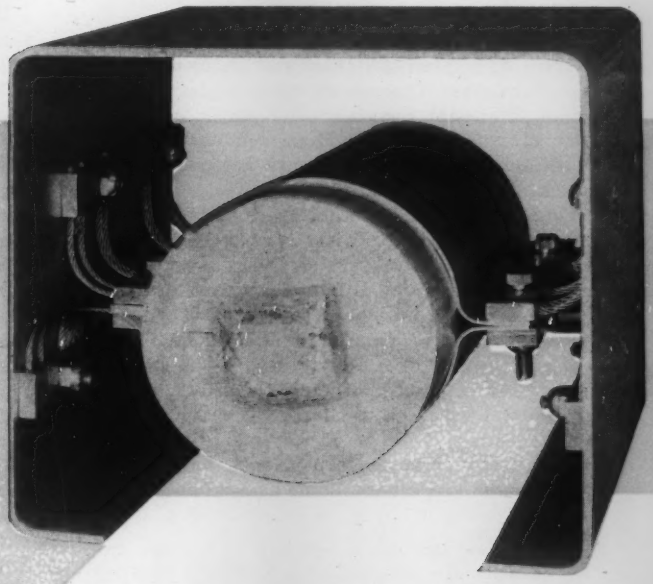
Clutch Automatically Disengages at Minimum Input and Output Speeds



An automatic centrifugal type clutch used on a portable gasoline-powered saw designed by the Harry A. Lowther Co. provides easy starting and maximum operator safety. The clutch, a product of Automatic Steel Products Inc., automatically engages above a certain engine speed and disengages instantly below this speed, or when the saw blade "pinches."

The saw blade, which is V-belt driven by an 8-hp engine can be positioned at any angle between a horizontal and vertical plane. To maintain desired V-belt tension, a patented "constant-center" drive is employed that keeps the belts in proper alignment.

Cable Vibration Mounts



A new technique for handling shock loads and high-frequency vibration

By R. G. Hartenstein and J. J. Kerley Jr.
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STANDARD techniques for minimizing noise and vibration often cannot handle shock loads, or vibration on top of steady-state loads. Lately, much has been done with antiresonance devices. For instance, mounting of sensitive equipment on cables has been studied and tested as an antiresonant barrier. Some uses include rotational couplings, translational mounts, three-dimensional mounts, and nonrotational isolation of antennas and gyros.

A sensitive mechanical device mounted on 7 by 19, 1/16-in. stainless-steel aircraft cord, Fig. 1, allows a three-dimensional isolation system. Mass of the mounted device is at the geometrical center of the attachment cables.

Each cable is a three-dimensional helix. No matter what motion the mounted device takes, every cable will bend, not snap. The antiresonant principle is thus evident; as amplitude builds up, twisting of the cable can never be absolutely uniform. A single cable twisting can break resonance.

At high frequencies the cables are so limber they have excellent noise attenuation. Under shock in any direction the cables can never completely

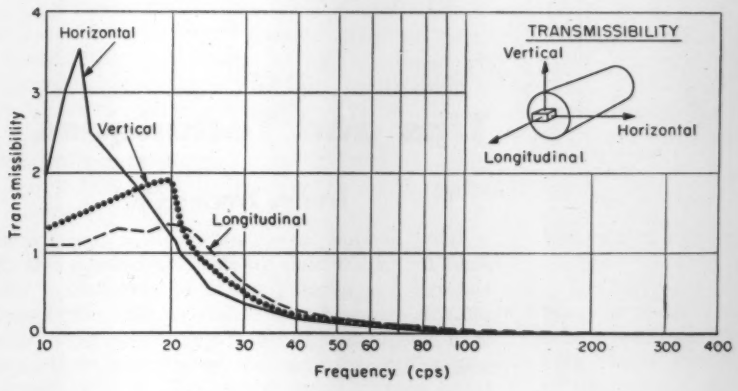


Fig. 1—Top—Cable vibration mount used to attenuate shock loads quickly and isolate high-frequency vibration.

Fig. 2—Left—Typical output response through a three-dimensional cable mounting system.

go into direct tension from the geometry of the cable formation. There is no bottoming or snapping action. Transient response after shock is a single-cycle attenuated motion. High-frequency transient vibrations of the base structure are not transmitted through the cable.

Thus, in a sense, the cables act as both a shock and vibration isolator with exceptional resistance to noise transmission. Fig. 2 shows a typical output response through this cable mounting system. Transmissibility is plotted in all three axes as an average of five tests on assemblies such as Fig. 1. Note the low transmissibility in the high frequency range. This characteristic offers an excellent noise barrier, particularly for sensitive equipment.

Many tests were performed with various windings, masses and inputs. Some general observations are:

1. Vibration and transmissibility in the low frequencies are comparable to standard vibration isolators.
2. Shock loads do not bottom the mounted mass but merely swing it into another plane. They die out in a single-cycle transient response.
3. High-frequency isolation is excellent.
4. Above resonance, the higher the input, the lower the transmissibility.
5. Vibration tests in conjunction with steady-state loads have been performed. Isolation is still effective. Natural frequency goes up, and transmissibility goes up. Since bottoming is eliminated, there is always a certain length of cable left to bend and thus isolate.
6. Temperature plus salt spray, high temperature and other environmental conditions are not critical since the mounting assembly is stainless steel.

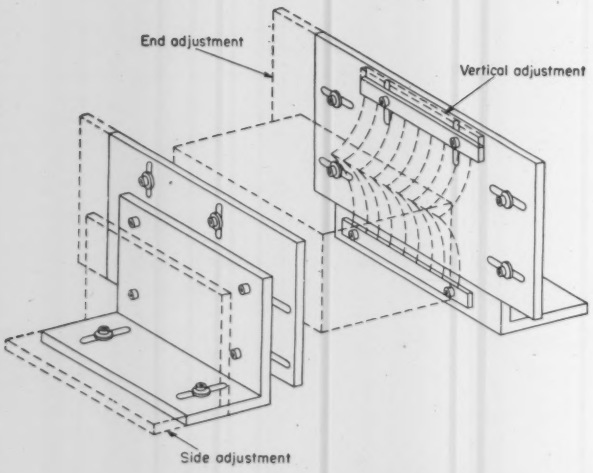


Fig. 3—Design jig used with a vibration table for finding the best cable lengths, spacings and positions.

Several design features should be carefully considered. If the bend in the cable is not proper, a standing wave will develop in the cables themselves. These loads may be too severe, and fatigue can result. Manufacturing techniques must not allow damage to the cables.

Note in Fig. 1 that the cables are initially designed with a large bend radius. Flexible cable such as 7 by 19, 1/16-in. or similar should be used. The mass isolated per cable should be kept low. Too few cables can cause fatigue. High endurance can be accomplished with proper adjustment. The configuration of the mounting in Fig. 1 has been vibrated for over 20 million times at resonance with a double amplitude of 0.06-in.

A typical design jig is shown in Fig. 3. The weight to be isolated required (1) a certain number of cables, (2) a certain length of cable, and (3) a certain stranding of cable. These three items are determined from previous tests. For Fig. 1, the stranding was 7 by 19, 1/16-in. stainless-steel cable with $1\frac{1}{4}$-in. long top cables and $1\frac{3}{4}$-in. long bottom cables. Total number of cables is 34.

The equipment is mounted in the testing jig and placed on the vibration table. The three dimensions of the jig are varied and transmissibility recorded through the entire frequency spectrum. The jig is then removed from the vibration table, rotated 90 degrees, and vibrated in another plane. This same procedure is followed in the third plane. Optimum cable lengths and spacings are thus recorded for maximum isolation.

It may be necessary during tests to increase or decrease the number of cables. It may further be necessary to purposely unbalance the upper and lower cables by making the upper cables longer or shorter than the lower cables, or by placing more or less cables on top than on the bottom.

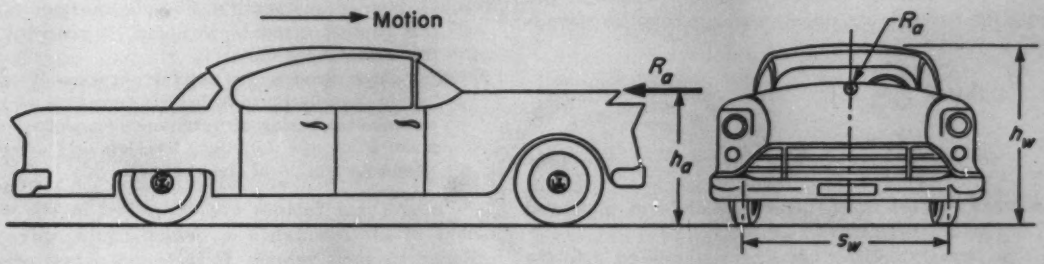
Other variables can be adjusted, but too much in the way of adjustment will require too much testing time. Hard, fast rules cannot be formulated, since this technique is new and sufficient data are not yet available. Effective mounting can be achieved by (1) holding the mass mounted per cable constant, (2) using no more than two or three cable strandings, and (3) using only two or three lengths of cables. Then the only variables left are the three spacing dimensions which can be designed right on the vibration table.

Tips and Techniques

Erasing Tracing Cloth

Ethyl acetate makes an excellent liquid erasing fluid for pencil lines on cloth. Dampen a soft cloth and rub the pencil lines to be removed. A cotton swab is handy for close places. The ethyl acetate does not injure the surface of the cloth in any way and pencil lines can be redrawn on the eradicated surface immediately.—R. T. WITHERSPOON, *Chemstrand Corp., Decatur, Ala.*

Fig. 43—The air-resistance force R_a is assumed to act at the centroid of the projected frontal area of the vehicle. As an approximation, the area can be taken as 0.9 (body height) (wheel tread), or 0.9 $(b_w)(s_w)$.



Mechanics of Vehicles—6

Resistance Forces

- air resistance
- inertia resistance
- transmission resistance
- performance diagrams

By Jaroslav J. Taborek*
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ROLLING resistance and grade resistance—two of the forces that impede the motion of a vehicle—were discussed in the preceding article of this series. Both were shown to be proportional to vehicle weight. This article continues the examination of such motion-impeding forces, discussing air resistance, inertia resistance and transmission resistance and the relationship of such forces to vehicle performance.

Air Resistance: According to the laws of aerodynamics, a body moving through the air is resisted by a force R_a, where

$$R_a = \frac{c_a \rho A v_r^2}{2g} \qquad (62)$$

In this expression, c_a is a dimensionless coefficient of air resistance (drag coefficient) with a value unique for each family of geometrically similar body shapes. Remaining terms in the equation are ρ, the air density (lb per cu ft), A, the projected area of the body in the direction of travel (sq ft), and v_r, the velocity of the body relative to the air (ft per sec).

Because of the influence of air density, magnitude of the air-resistance force depends on the state of the air, i.e., the barometric pressure and temperature. The following relation relates density to pressure and temperature:

$$\rho = \frac{144p}{RT} = \frac{1.32p'}{460 + t} \qquad (63)$$

Symbols in this expression are defined in Nomenclature.

The influence of changes in air density must be taken into account in accurate performance calculation, since differences between density extremes may reach 20 per cent or higher. For example, at an altitude of 4000 ft, air density is only 83 per cent of the sea-level value.

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For many performance calculations, however, the density for "normal" or standard atmospheric conditions (60 F and 29.9 in. Hg) provides sufficient accuracy. In such cases, $\rho = 0.0763$ lb per cu ft is used as a constant value.

By substitution of the standard density, the equation for the air resistance can then be simplified to read

$$R_a = 0.12\, c_a A \left(\frac{v_r}{10} \right)^2$$

$$= 0.26\, c_a A \left(\frac{V_r}{10} \right)^2 \qquad (64)$$

where V_r is the speed of the vehicle in mph and v_r in fps, both relative to the air.

The physical origin of air resistance on vehicles is derived from three sources:

1. Drag resistance, which is a function of the aerodynamic shape of the body with respect to all outside surfaces. Protruding objects like mirrors, exhaust mufflers, license plates, etc., can increase drag resistance considerably at higher speeds. Of special importance is the shape of the rear part of the body, which determines the amount of turbulence in the wake of the vehicle.
2. Air friction on the outside surfaces or "skin" of the body. For the more or less standardized quality of surface finish on passenger cars, this portion amounts to about 10 per cent of the total air resistance.
3. Air flow through the car for purposes of cooling or ventilating. This influence can be resistance-increasing or resistance-decreasing, depending on the function, location and aerodynamic perfection of the channels.

These three factors are expressed in the coefficient of air resistance c_a, which has a value particular to each vehicle. It is found experimentally in scale model wind-tunnel tests and is confirmed by coasting tests performed on actual vehicles.

In some literature sources, the air-resistance coefficient is given as

$$C_a = \frac{c_a \rho}{2g} = 0.26\, c_a \left(\frac{\text{lb-sec}^2}{\text{ft}^4} \right) \qquad (65)$$

where the factor C_a includes the effect of the state of the air and is not a dimensionless number. Equation 64 can be rewritten to incorporate C_a, giving

$$R_a = C_a A \left(\frac{V_r}{10} \right)^2 \qquad (66)$$

Average values of c_a and C_a at SAE standard air conditions for representative vehicles are given in Table 4.

While the coefficient of air resistance c_a is a function of the aerodynamic perfection of a body, the important criterion for comparison of vehicles is the product of the coefficient with the frontal area, i.e., $A(c_a)$. There are cases where, when the frontal area is enlarged, the total resistance is reduced

Nomenclature

- A = Projected vehicle area in drive direction, sq ft
- a = Acceleration, ft per sec^2
- C_a = Coefficient of air resistance, lb-sec^2-ft^{-4}
- c_a = Coefficient of air resistance, dimensionless
- E = Kinetic energy, ft-lb
- g = Acceleration of gravity, ft per sec^2
- I = Moment of inertia, ft-lb-sec^2
- I_w = Polar moment of inertia of wheels, ft-lb-sec^2
- M = Torque, lb-ft
- M_i = Torque required for accelerating rotating parts, lb-ft
- m = Mass, lb-sec^2-ft^{-1}
- m_e = Equivalent mass, lb-sec^2-ft^{-1}
- m = Total effective mass of vehicle, lb-sec^2-ft^{-1}
- N = Power, hp
- p = Pressure, lb per sq ft
- p' = Barometric pressure, in. Hg
- R = Gas constant (=53.3)
- R_a = Air resistance, lb
- R_g = Grade resistance, lb
- R_i = Inertia resistance, lb
- R_{it} = Inertia resistance of translatory mass, lb
- R_r = Rolling resistance, lb
- r = Rolling radius of tire, ft
- s_w = Wheel tread, ft
- T = Absolute temperature, deg Rankine
- t = Temperature, deg F
- V = Speed, mph
- V_r = Speed relative to air, mph
- v = Speed, ft per sec
- v_r = Speed relative to air, ft per sec
- W = Weight, lb
- α = Angular acceleration, rad per sec^2
- γ = Mass factor for rotating parts
- ζ = Reduction ratio
- η = Efficiency or efficiency factor
- ρ = Density, lb per ft^3
- ω = Angular velocity, rad per sec

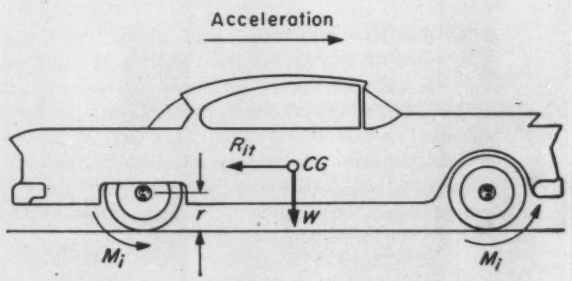


Fig. 44—Inertia force of the translating vehicle mass acts at the cg and is always directed against the acceleration vector. Translatory acceleration is necessarily accompanied by angular acceleration of the wheels and the drive-system components. As a means for simplifying performance calculations, the effects of rotational inertia of such parts can be represented by an equivalent translatory mass.

because of a resulting lower c_a value. This occurs, for example, when a protruding part is covered with a streamlined fairing.

The hypothetical point of action of the air-resistance force, Fig. 43, is the centroid of the projected area in the drive direction. Usual frontal areas (in sq ft) on present-day cars are: (1) Passenger cars (small), 14-20; (2) Passenger cars (standard), 22-30; (3) Buses and trucks, 60-80. Areas can also be estimated as 0.9 (*body height*) (*wheel tread*).

Combining Equation 64 with Equation 51 (Part 5), power N_a necessary to overcome air resistance is

$$N_a = \frac{0.0026\, c_a\, A\, V_r^2\, V}{375} \text{ (hp)} \qquad (67)$$

where again V_r is the relative speed of the vehicle against the air and V is the ground speed of the vehicle, both in mph. For calm air $V_r = V$ and

$$N_a = \frac{0.0026\, c_a\, A\, V^3}{375} = 0.07\, c_a\, A \left(\frac{V}{10} \right)^3 \qquad (68)$$

From this equation, it is seen that the power requirement is proportional to the third power of the speed.

Inertia Resistance: Every change of speed of a moving body is opposed by an inertia force which is proportional to the product of the mass of the body and the time rate of speed change. For vehicles considered herein, this force will be referred to as the inertia resistance R_i and will always be directed against the vector of acceleration (or deceleration for decreasing speed). The point of action of this force is ideally located at the center of gravity of the vehicle mass, Fig. 44.

Considering first only the translatory mass of the vehicle, the inertia resistance R_{it} is given by

$$R_{it} = m \left(\frac{dv}{dt} \right) = \frac{Wa}{g} \qquad (69)$$

where m is the mass of the vehicle and a is the translatory acceleration.

The state of translatory motion of a vehicle is inseparably coupled to the rotational speed of the wheels which, in turn, are positively connected to the rotating parts of the drive mechanism. Any change of translatory speed must, therefore, be accompanied by a simultaneous change in the rotational speed of all such parts.

For calculation of the torque M necessary to accomplish the change of the rotational speed, $d\omega$, use is made of the basic equation

$$M = I \left(\frac{d\omega}{dt} \right) = I\alpha \qquad (70)$$

where M is torque, I is moment of inertia about the axis of rotation, and α is angular acceleration (see Nomenclature for dimensions).

With this equation applied to a vehicle with several groups of parts, each rotating at a different speed, the respective torques can be related to the drive-axle by

$$M_i = \sum M\zeta = \sum I\alpha\zeta \qquad (71)$$

where M_i is the inertia resistance torque of all rotating parts reduced to the drive axle, and ζ is the reduction ratio between the drive axle and a particular part.

From the speed and acceleration relationships

$$\omega = \omega_d\, \zeta \qquad (72)$$

and

$$\alpha = \alpha_d\, \zeta \qquad (73)$$

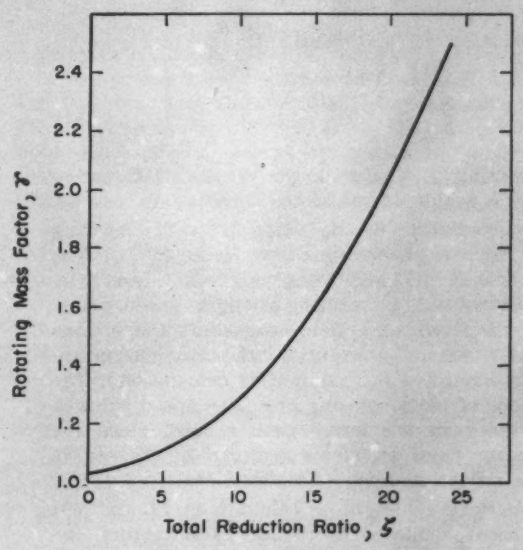


Fig. 45—Mass factor γ, representing the effect of the rotating parts on the inertia mass of the vehicle, is plotted here as a function of the total reduction ratio ζ between the drive axle and the engine.

Table 4—Air-Resistance Coefficients

Vehicle Type	c_a (dimensionless)	C_a* (lb-sec²-ft⁻⁴)
Passenger car	0.4-0.5	0.104-0.13
Convertible	0.6-0.65	0.155-0.17
Racing car	0.25-0.3	0.078-0.065
Bus	0.6-0.7	0.155-0.182
Truck	0.8-1.0	0.208-0.260
Tractor-trailer	1.3	0.338
Motorcycle and rider	1.8	0.470
Geometrical Bodies:		
Sphere	0.47	0.122
Square plate	1.2	0.31
Streamlined body	0.1	0.026

*$C_a = 0.26\, c_a$

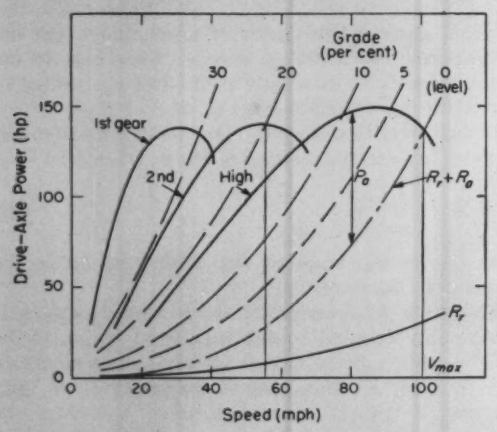


Fig. 46—Vehicle power diagram. Power required to overcome rolling, air and grade resistances is additively plotted against vehicle speed. Engine power delivered to the drive axle in first, second and high gears is also given. Curve summing rolling and air-resistance forces intersects high-gear power-available line at 100 mph, indicating maximum vehicle speed on level ground. In second gear, a 20 per cent grade can be negotiated at a speed of 55 mph. Difference between power required and power available is free or excess power for acceleration.

Equation 71 can then be written as

$$M_i = \alpha_d \sum I\zeta^2 \tag{74}$$

where the subscript d refers to the driving axle.

Equivalent Mass: To simplify calculation of the effects of rotating parts on total inertia resistance, use can be made of the fact that circumferential speed at the rolling radius of the tire is equal to the translatory speed of the vehicle (neglecting slip). An equivalent mass m_e can be determined which, hypothetically concentrated at the rolling radius r, will have the same effect on the inertia of translatory motion as the summation of inertia torques of individual rotating parts. The equivalent mass m_e can be calculated from

$$M_i = m_e r^2 \alpha_d = \alpha_d \sum I\zeta^2 \tag{75}$$

Solving for m_e,

$$m_e = \frac{\sum I\zeta^2}{r^2} \tag{76}$$

Mass m_e can be added to the translatory mass m of the vehicle, giving the effective inertia mass of the vehicle, m'. It often proves convenient to express the effective mass m' in terms of the vehicle mass m, or

$$m' = m + m_e = m\gamma \tag{77}$$

where γ is a dimensionless mass factor of the rotating parts that defines how much the effective mass exceeds the actual mass of the vehicle.

By use of the factor γ, Equation 69 can be rewritten to give the total inertia resistance of the vehicle, or

$$R_i = \gamma ma \tag{78}$$

Equation 78 can also be derived by an energy method. From the theorem that the change in kinetic energy of a body equals the work produced by external forces

$$dE = \left(P - \sum R_x \right) ds \tag{79}$$

where E is the kinetic energy of the moving vehicle, P is tractive force, and ΣR_x is the summation of all resistance forces except R_i.

From the equilibrium of forces, the following relation applies:

$$R_i = P - \sum R_x \tag{80}$$

Further, the kinetic energy of the vehicle is

$$E = \frac{mv^2}{2} + \sum \frac{I\omega^2}{2} \tag{81}$$

Differentiating this equation,

$$dE = mv(dv) + \sum I\omega(d\omega) \tag{82}$$

Combining Equations 79 through 82,

$$R_i(ds) = mv(dv) + \sum I\omega(d\omega) \tag{83}$$

Separating R_i and substituting $ds/dt = v = r_{\omega_d}$ and Equation 72,

$$R_i = \left(\frac{dv}{dt} \right) \left(m + \frac{\Sigma I\zeta^2}{r^2} \right) \tag{84}$$

Substituting further with the results of Equation 76, an equation identical to Equation 78 results.

For calculation of the value of γ, the rotating parts can be divided into two groups: (1) The vehicle wheels (both front and rear), and (2) Parts translating or rotating at engine speed, principally the flywheel, clutch, crankshaft and pistons (manual transmission parts, gears and shafts are usually neglected in a simplified calculation). The influence of parts rotating at engine speed gains in importance in the lower gear ranges, since the equivalent mass m_e is proportional to the square of the reduction ratio (Equation 76).

Numerical values of γ (Equations 77 and 78) have been calculated by several investigators. Reliable values are quite difficult to obtain because the inertia moment of most engine parts has to be measured experimentally. Average values of γ collected from the literature are given for capacity-loaded vehicles in Table 5.

An excellent method of calculation is presented in Reference 36 and is explained by the following

development:

Rearranging Equation 77,

$$\gamma = 1 + \frac{m_e}{m} = 1 + \left(\frac{\Sigma I_w}{mr^2} + \frac{\Sigma I \zeta^2}{mr^2} \right) \quad (85)$$

where ΣI_w is the inertia moment of the wheels and I is the inertia of any part rotating at engine speed with speed ratio ζ with respect to the driving axle.

As a representative average from a number of calculations, γ can be expressed as function of the reduction ratio ζ, Fig. 45.

$$\gamma = 1 + (0.04 + 0.0025\,\zeta^2) \quad (86)$$

From this expression, factor γ corresponding to any given ratio can be calculated. The applicability of this calculation method for all road vehicles and for a relatively wide range of capacities is substantiated by the fact that the size of drive components, within the usual limits, is proportional to the vehicle capacity. Results of the equation are fairly accurate and are useful for preliminary performance calculations.

Transmission Resistance: Transmission resistance is not a resistance force in the same sense as the other motion-resisting forces. It represents, rather, the power consumed in the process of transmitting engine power to the driving wheels and is due mainly to the following elements:

1. Clutch, transmission, differential, universal joints and bearings. Power consumption in these components is function of both the quality of lubrication and the surface finish of the gears and is proportional to power transmitted.
2. Oil churning in the gear box. Power consumption in this respect is proportional to engine speed and is also a function of oil viscosity.

For vehicles in motion, the measure of transmission resistance is usually given as the efficiency η of the complete power train between the engine and the drive axle and is measured experimentally on a dynamometer. Preliminary design calculations are based on comparative data of existing similar applications. The breakdown of the overall efficiency factor into component subfactors delivers these average values: (1) Clutch efficiency, 0.99; (2) Gear shift transmission efficiency, in direct gear 0.98, in lower gears 0.95; (3) Differential efficiency, 0.95; (4) Joints and bearing efficiency, 0.99-0.98.

Efficiency of the whole power train is then the product of the efficiency factors of all the components, resulting in the following average overall transmission efficiencies on present-day vehicles: (1) In direct gear, 0.90; (2) In lower gears, 0.85; (3) In transmissions with very high reduction, 0.75-0.80.

For calculations on vehicles coasting with the engine disconnected, torque M_t required on the drive axle to overcome transmission resistance is used. Its value can be found experimentally on dynamometers or by trailing tests. In equation form,

$$R_t = \frac{M_t}{r} \quad (87)$$

where R_t is the transmission resistance force.

Vehicle Performance: Calculation of the resistance forces supplies data essential to vehicle performance prediction. As a rule, performance is obtained by one of the following graphical methods.

POWER DIAGRAM: Power required to overcome rolling, air and grade resistance forces (Part 5)

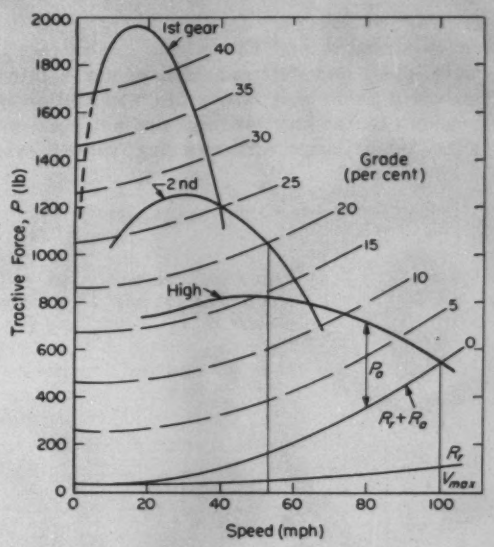


Fig. 47—Tractive-force diagram. Rolling, air and grade resistances are plotted additively against vehicle speed. Superimposed on the family of force-required curves is tractive force P available at the drive wheels in various gears. Maximum speed is given by the intersection of the (R_r + R_a) curve with the high-gear tractive-force line. Speed at which a 20 per cent grade can be negotiated is 55 mph in second gear. Difference between the force-required and force-available curves is free or excess force for acceleration.

[36] J. L. Koffman—"Vehicle Performance (The Effect of Rotating Masses on Acceleration)", Automobile Engineer, London, Dec. 1955.

Table 5—Average Values of Mass Factor*

Vehicle Type	Gear			
	High	Second	First	Low
Passenger car (large) ..	1.09	1.14	1.30	...
Passenger car (small) ..	1.11	1.20	1.50	2.40
Truck	1.09	1.20	1.60	2.50

*Capacity-loaded vehicles.

is graphically plotted against vehicle speed on the power diagram. On the same diagram engine power delivered to the drive axle at different gear reductions is plotted, Fig. 46. From the intersections of these power-required and power-available curves, the expected vehicle performance at any speed and grade can be determined directly or, conversely, the power necessary to reach a certain performance level can be established.

TRACTIVE-FORCE DIAGRAM: In this method, rolling, air and grade-resistance forces are additively plotted in the given order against vehicle speed, Fig. 47. The tractive force available at the drive wheels in the different gear reductions is also superimposed on the diagram. Intersections of the two sets of curves give the graphical solution to the equation

$$\frac{M_e \eta \zeta}{r} = P = R_r + R_a + Rg \qquad (88)$$

where M_e is engine torque (lb-ft) as function of speed, η is power transmission total efficiency, and ζ is the total reduction ratio between engine and drive axle.

Corresponding curve intersections indicate the tractive force (and therefore engine torque) required to balance the resistance forces at any given speed and condition of operation. The tractive-force diagram generally is preferable to the power diagram because, at very low speeds, the power requirement and the engine power output are very small and determination of curve intersections is difficult and inaccurate. Calculation of performance by the tractive-force method, however, gives relatively large corresponding values, even at zero speed and permits more exact graphical analysis.

Both performance-prediction methods apply only for constant-speed driving; performance calculation in accelerated motion is more complicated and cannot be solved by a direct method. Detailed investigation of the complete subject of vehicle performance prediction in constant and accelerated motion is discussed in a subsequent article in this series.

Summary of Resistance-Force Characteristics: Comparing resistance forces, the following observations can be made:

1. Rolling and air resistance are present under all conditions of motion. Tractive force is used principally to overcome these two resistance forces. Only if excess traction is available will the vehicle accelerate or climb grades.
2. All the resistance forces except air resistance are proportional to vehicle weight. Nevertheless, a relationship between vehicle weight and frontal area (or coefficient of air resistance) is apparent, since high-capacity vehicles are usually designed for large loads and lower speeds and therefore do not require an aerodynamically clean body shape.
3. Rolling and air resistance are functions of vehicle speed, while grade and inertia resistance are independent of speed.
4. Comparison of air and rolling resistance forces, Fig. 48, shows, as a function of speed, the percentile share of these resistances in the total. Generally, it can be observed that the effect of the air resistance at a certain speed is more pronounced on a light passenger car, despite its aerodynamically superior quality, than on a

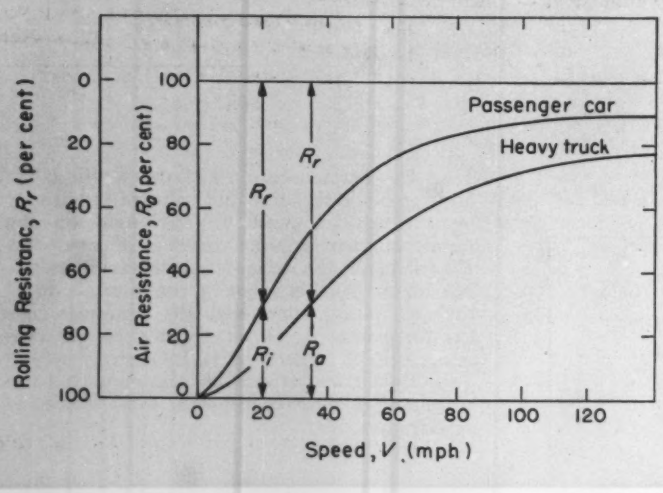


Fig. 48—Comparison of rolling and air resistances for passenger car and heavy truck. For the car: W = 3000 lb, c_a = 0.5, and A = 30 ft²; for the truck: W = 30,000 lb, c_a = 0.8, and A = 70 ft². Coefficient of rolling resistance on both vehicles is assumed as $f = 0.01(1 + V/100)$. Assuming, arbitrarily, that air resistance is of no practical importance until it reaches 30 per cent of rolling resistance, it is found that this value is reached at 20 mph for the passenger car and 35 mph for the truck. At a cruising speed of 70 mph, air resistance accounts for 80 per cent of the tractive force on the passenger car, but only 60 per cent on the truck. This fact justifies the emphasis placed on the aerodynamic design of passenger cars.

heavy truck. Considering the cruising speed on modern highways as 70 mph, it is found that an average passenger car will use 80 per cent of its tractive force to overcome air resistance. The necessity for aerodynamic perfection, especially on small cars operated at high speeds, is evident.

On the other hand, air resistance does not become appreciable until a certain speed is reached. Assuming that air resistance will be considered only after it reaches at least 30 per cent of rolling resistance ($R_a = 0.3\ R_r$), it is found that air resistance is negligible on passenger cars for speeds below 20 mph and on trucks below 35 mph. Rolling and air resistances are equal at speeds of about 35 and 55 mph, respectively (Fig. 48).

5. Similarity of the characteristics of grade and inertia resistances enables mathematical comparisons to be made. The excess tractive force will produce either an acceleration a (ft per sec^2) or enable the vehicle to climb the grade G (per cent). From Equations 61 (Part 5) and 78, the following relation can be derived:

$$a = \frac{gG}{100\gamma} \qquad (89)$$

Correspondingly, if maximum acceleration on level ground is known, the acceleration a_g while the vehicle is ascending grade G can be calculated as

$$a_g = a - \frac{gG}{100\gamma} \qquad (90)$$

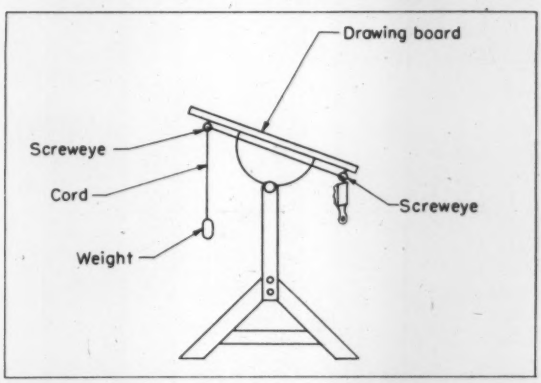
Therefore, the same excess tractive force will produce either a 10 per cent grade-climbing ability or an acceleration of 0.1 (g/γ) ft per sec^2.

In the next part of this series, the effects of weight distribution on vehicle static and dynamic stability (against tipping) are reviewed. Experimental and analytical methods for determining the vehicle center of gravity are also presented.

Tips and Techniques

Pencil-Sharpener Aid

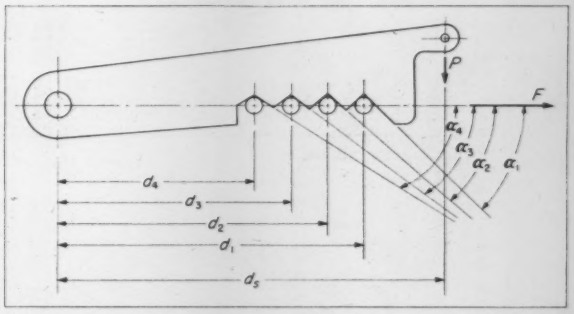
A sanding pad for pencil sharpening can be rigged so that it is readily available for easy use, yet is not on the table surface nor hanging where is will soil the draftsman's clothing. Two screweyes are fastened to the bottom surface of the drafting



board. A cord is fastened to the sandpaper paddle at the end opposite the handle. The card runs through the screweyes and a weight is fastened to the end. A piece of chessecloth, or tissue, stapled to the back of the paddle is convenient for wiping the sharpened lead.—S. B. SPRAGUE, *Deltec Inc., Youngstown, O.*

Multistep Detents

In the area of small-machine design, multistep detent actions are often used. One of the most economical designs consists of a detent pawl and spring, either a single element or two used together in scissor fashion. If a constant actuating force, F, is desired at each position of the detent, the angle of the detent must change for each step.



These angles can be found readily by using a pair of simple equations. The distance from the pivot to the point of spring pressure, d_s, must be known, as must the desired release force, F, and the dimensions d_1, d_2, d_3, d_4, etc.

For best efficiency, angle α_1 should not exceed 45 degrees. The required spring pressure for the first detent, P, is found and then used as a constant for finding the angle of the other detents.

$$P = \frac{Fd_1}{d_s} \cot \alpha_1$$

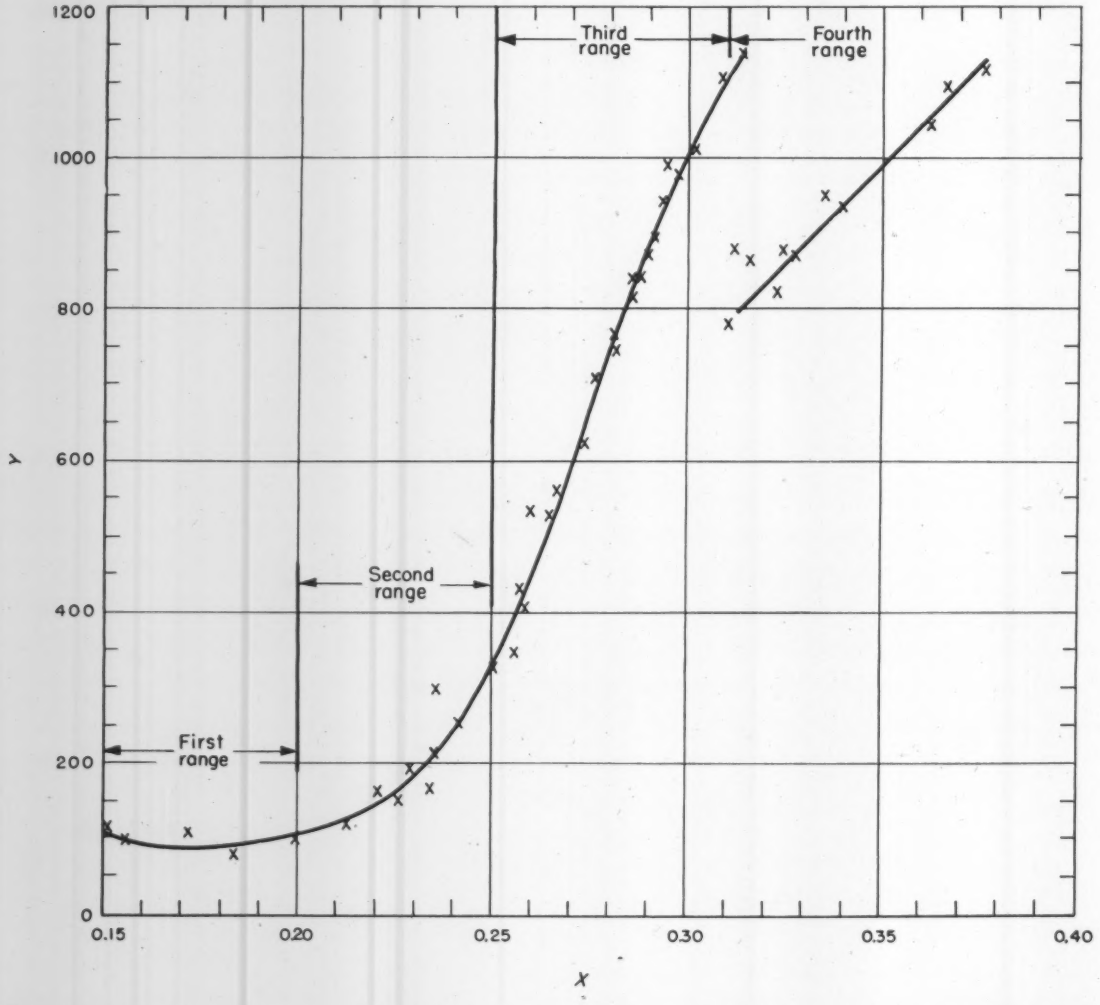
The angle of detent for the other steps is found by substituting P in equation

$$\cot \alpha_n = \frac{d_s P}{Fd_n}$$

—REGINALD GALLANT, *Underwood Corp., Bridgeport, Conn.*

Fitting Equations by Method of Least Squares

Fig. 1—Typical plot of raw data. Curve provides relatively "smooth" data points from which to find differences and, hence, ranges and their order, Tables 1 and 2. Actual points, however, are used to find final equations by method of least squares, as demonstrated by example on Page 111.



By Charles I. Tiplitz
Chief Engineer
J. M. Lehmann Co. Inc.
Lyndhurst, N. J.

FITTING equations to curves and data involving only two variables is a problem of varying complexity and urgency. Where simple relations are plotted, no difficulty follows. However, complex relations can be time-consuming. One method of fitting equations to empirical data has recently been outlined by Cox.[1] Admitted limitations of this simplified method make it inapplicable for many field observations.

Empirical data may have a random spread which obscures and prevents isolating or stripping off the higher-power differences and terms. This is common outside laboratories where equations need to be fitted to extensive performance data without knowledge of the exact form of the equation.

As an example, suppose $y = A \log x + B \sin x$ were measured under field conditions where random measurement errors were large. If the form of the equation were known, A and B could be determined easily. However, all too often the form is not known or can not be discovered easily and it is better to assume a power series,

$$y = A_0 + A_1x + A_2x^2 + \ldots + A_mx^m \qquad (1)$$

and attempt to fit it to the data by the method of least squares. Even so, such curves take time, and there are no consistently reliable short cuts. Proper application of the method, however, will minimize the labor.

The theory of least squares is better known than its application. Equation 1 provides theoretical values, y, at each x_i ($i = 1, 2, 3, \ldots, n$, which match data points 1, 2, 3, . . ., n). Theoretical y values are intended to fit the actual values of y_i closely. The method of least squares is a way of evaluating the coefficients, $A_0, A_1, \ldots, A_m$, so that the fit is better than for any other set of coefficients. In particular and more precisely, the sum of the squares of the errors is less for the designated values than for any other set of coefficients. The conditions which result from this requirement on the coefficients are called the normal equations[2] and are:

$$\begin{aligned}
\Sigma y_i &= A_0n + A_1\Sigma x_i + A_2\Sigma x_i^2 + \ldots + A_m\Sigma x_i^m \\
\Sigma x_i\, y_i &= A_0\Sigma x_i + A_1\Sigma x_i^2 + \ldots + A_m\Sigma x_i^{m+1} \\
&\vdots \\
\Sigma x_i^m\, y_i &= A_0\Sigma x_i^m + A_1\Sigma x_i^{m+1} + \ldots + A_m\Sigma x_i^{2m}
\end{aligned} \qquad (2)$$

Since there are $m + 1$ simultaneous equations, the higher-degree power series take more time to solve. Furthermore, the time to determine each sum (Σ) is proportional to the number of points, n.

Computing time can be minimized by choosing the lowest-degree power series justified by or corresponding to the accuracy of the data. The method described by Cox[1] is easily adapted for this purpose.

First, the curve must be divided into ranges

Table 1—Points from Curve and Differences for Two Ranges

Range	x	y	Δy	$\Delta^2 y$	$\Delta^3 y$	$\Delta^4 y$
First	0.15	106				
			−10			
	0.16	96		5		
			− 5		0	
	0.17	91		5		
			0		0	
	0.18	91		5		
			5		0	
	0.19	96		5		
			10		0	
Second	0.20	106		5		
			15			
	0.21	121				
	0.22	145				
	0.23	183				
	0.24	241				
			85			
Third	0.25	326		35		
			120		−13	
	0.26	446		22		−1
			142		−14	
	0.27	588		8		1
			150		−13	
	0.28	738		−5		1
			145		−12	
	0.29	883		−17		−2
			128		−14	
	0.30	1011		−31		
			97			
Fourth	0.31	1108				
	0.32	832				
	0.33	885				
	0.34	938				
	.	.				
	.	.				
	.	.				

[1]References are tabulated at end of article.

throughout which its nature does not change. This can sometimes be determined from inspection of the plotted points. Second, the degree or the highest power in the presumed power series, must be chosen. Usually, equations above the fourth degree are not practical for widely scattered data. Furthermore, solutions presuming equations with degree greater than half the number of points in each range converge slowly and inaccurately and are not advisable. For example, assume data distribution as shown in Fig. 1. Five points are in the first range ($n = 5$) and should be described by a second degree equation ($m \leq 2$).

Where the curve ranges and degree can't be fixed simply, first, second, and higher-order differences (Δy, $\Delta^2 y$, etc.) must be tabulated the way suggested by Cox. The field data may not be available at regular intervals of the independent variable, x. Instead the differences must be chosen from regularly spaced values read from a curve through the points. Precision at this stage is not critical since the points so chosen only distinguish range changes and the degree of the power series. The basic data are used in the actual computations when the accuracy becomes critical. Returning to Fig. 1, the interval in x is by no means regular. However, points can be read from the curve as in Table 1.

Theoretically the $(m + 1)$th difference (third in the first range of Table 1) is zero. Therefore, successively higher order differences must be taken until they become zero. This fixes $m + 1$ and hence m in Equation 1. In the first range of Table 1. for example, $m = 2$ and

$$y = A_0 + A_1 x + A_2 x^2 \qquad (1a)$$

In practice, with relatively poor measurements, no order of differences is likely to be zero. Instead, inspection determines at what order successive differences become random. The degree of the equation, if known, may actually be higher than the order where inaccuracy and scatter obscure trends. However, lower-degree equations fit as well or better, and certainly take less time to solve and use. For example, in the third range of Table 1 the average value of the fourth-order differences is considerably less than the average spread. Therefore, these data should be fitted to a third-degree equation.

The curve ranges are bounded where adjacent identical-order differences differ by more than the usual amount. The ranges can also be determined by comparing the order in which differences approach zero or random values. The third-order differences in the first range of Tables 1 and 2 are zero. In the adjacent group, Tab'e 2, these differences are not zero, and it is the fifth-order differences which are zero. Therefore the nature of the curve is considered to change at the point midway between the zero differences ($x = 0.21$).

Table 2 embraces four ranges. The third range would be a fourth-degree equation. Isolated and exceptional differences or discontinuities confirm the location of range changes. Note the values 4

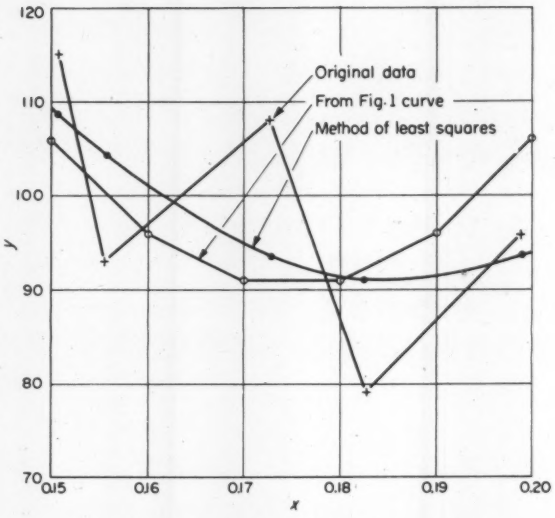


Fig. 2—Large-scale plot of first range, Fig. 1.

Table 2—Points from Curve and Their Differences

Range	x	y	Δy	$\Delta^2 y$	$\Delta^3 y$	$\Delta^4 y$	$\Delta^5 y$
First	0.15	106					
			−10				
	0.16	96		5			
			− 5		0		
	0.17	91		5			
			0		0		
	0.18	91		5			
			5		0		
	0.19	96		5			
			10		0		
Second	0.20	106		5		4	
			15		4		− 3
	0.21	121		9		1	
			24		5		0
	0.22	145		14		1	
			38		6		0
	0.23	183		20		1	
			58		7		0
	0.24	241		27		1	
			85		8		−22
Third	0.25	326		35		−21	
			120		−13		
	0.26	446		22		− 1	
			142		−14		
	0.27	588		8		1	
			150		−13		
	0.28	738		− 5		1	
			145		−12		
	0.29	883		−17		− 2	
			128		−14		
	0.30	1011		−31			
			97				
Fourth	0.31	1108					
			−276				
	0.32	832					
			53				
	0.33	885					
			53				
	0.34	938					
	.	.	.				
	.	.	.				
	.	.	.				

and -21 in the fourth-order differences. The lower the order that the discontinuity is in, the more distinct the change appears. The interval between $x = 0.31$ and 0.32 is discontinuous in the first order and defines a range change that is evident in Fig. 1. Each range must be treated separately to minimize computing time and achieve a good fit.

Once the degree and range of the equation or equations have been determined, each equation is solved independently by identical methods and using only those points in its range. First, products, squares, cubes, etc., must be summed. Second, $m + 1$ simultaneous equations must be solved.

Example—Method of Least Squares

For the first region of the curve in Fig. 1, actual x and y values are used to obtain the following data:

y_i	x_i	$x_i^2 \times 10^2$	$x_i^3 \times 10^3$	$x_i^4 \times 10^4$	$x_i\, y_i$	$x_i^2\, y_i$
115	0.1508	2.274064	3.429288	5.171367	17.3420	2.6151736
93	0.1554	2.414916	3.752779	5.831819	14.4522	2.2458719
108	0.1728	2.985984	5.159780	8.916100	18.6624	3.2248627
79	0.1827	3.337929	6.098396	11.141770	14.4333	2.6369639
96	0.1990	3.960100	7.880599	15.682392	19.1040	3.8016960
Totals						
491	0.8607	14.972993	26.320842	46.743448	83.9939	14.5245681

Table 1 has shown that a second-order equation may be used. That is,

$$y = A_0 + A_1 x + A_2 x^2$$

Tabulated totals above are next substituted in normal Equations 2:

$$\Sigma y_i = A_0 n + A_1 \Sigma x_i + A_2 \Sigma x_i^2$$

$$491 = 5A_0 + 0.8607A_1 + 0.14972993A_2$$

$$\Sigma x_i\, y_i = A_0 \Sigma x_i + A_1 \Sigma x_i^2 + A_1 \Sigma x_i^3$$

$$83.9939 = 0.8607A_0 + 0.14972993A_1 + 0.026320842A_2$$

$$\Sigma x_i^2\, y_i = A_0 \Sigma x_i^2 + A_1 \Sigma x_i^3 + A_2 \Sigma x_i^{2(2)}$$

$$14.5245681 = 0.14972993A_0 + 0.026320842A_1 + 0.0046743448A_2$$

These three equations are then solved simultaneously, and the coefficients are: $A_0 = 604.5$, $A_1 = -5542$, and $A_2 = 14{,}952$. The final form of the equation is

$$y = 604.5 - 5542x_i + 14{,}952x_i^2$$

Solving for y at each x_i gives

x_i	y	x_i	y
0.1508	108.7	0.1827	91.0
0.1554	104.3	0.1990	93.7
0.1728	93.3		

These points are shown in the comparative plot of Fig. 2.

The accompanying example shows application of the method to the first range of Fig. 1, and Fig. 2 shows the several stages compared at large scale. If the amount of data is large or m is 3 or greater, the amount of manual computation may be discouraging.

In such cases the best way to handle the computing is through the use of subroutines available on electronic digital computers. One subroutine computes the sums, and a second routine will solve $m + 1$ equations with $m + 1$ unknowns in a very short time. It is important to realize that the computers can do this so reliably and cheaply that a curve-fitting problem previously considered so tedious and complex as to be abandoned is within easy reach. In fact, it frequently becomes more attractive to subject data to this technique consistently than try to deduce the exact form of the equation.

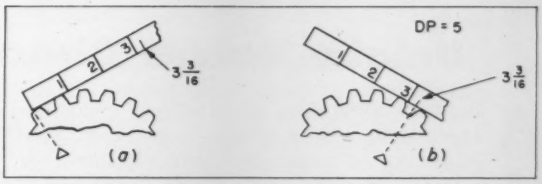
REFERENCES

1. A. Bruce Cox—"Fitting Equations to Experimental Data," MACHINE DESIGN, Jan. 24, 1957, Pages 95-99.
2. *Mathematical Tables from Handbook of Chemistry and Physics*, Chemical Rubber Publishing Co., Cleveland, Eighth Edition, Page 254.

Tips and Techniques

Determining Diametral Pitch

The diametral pitch of a gear can be quickly determined by using a common scale. The scale is set with the zero mark against the upper edge of the tooth face, a. Keeping the scale in contact with the gear, it is rolled over the teeth, b, until $3\frac{3}{16}$ in. is reached. The diametral pitch is the number of complete teeth within $3\frac{3}{16}$ in. of circumference. — TADASHI MATUMOTO, *Nishi-Oita, Japan.*



Eliminating Redrawing

Time can be saved in making possible future alterations to a drawing if leaders and arrows from notes are drawn on the back surface of the drawing. If the notes or arrows are changed, no useful lines in the drawing itself need be erased and replaced.—D. F. TOUCH, *draftsman, Airborne Instrument Co., Mineola, N. Y.*

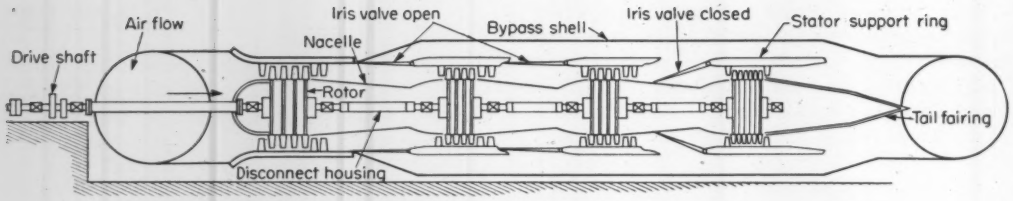


Fig. 1—Output of this supersonic compressor is regulated by opening or closing the iris valves to either bypass air through the bypass shell or direct it to the next compressor stage. This view shows three stages in operation. The fourth stage is being bypassed.

Fig. 2—Hydraulic cylinders, one per leaf, move valve leaves between positions. Piston rods are attached to a sliding crosshead at the cylinder. Airfoil-section leaf-operating rods are pinned to a cast-steel bracket which forms part of the leaf.

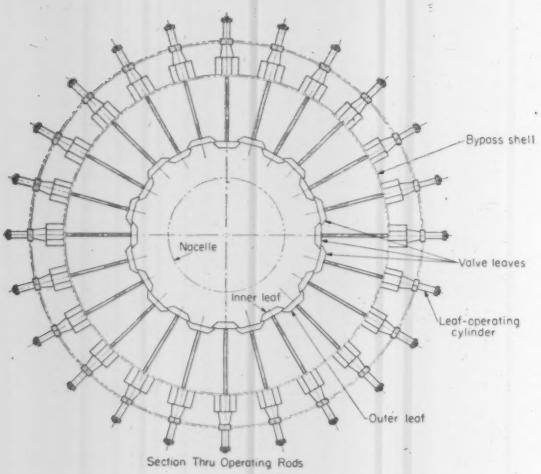
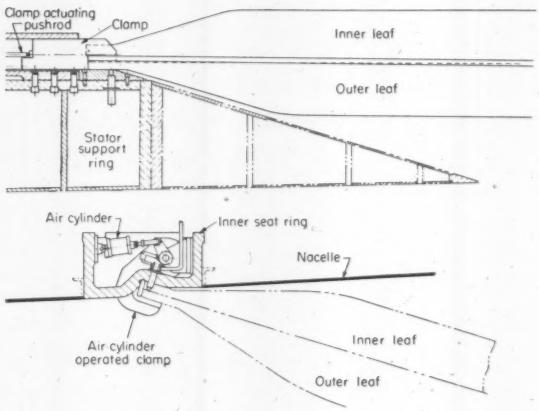


Fig. 3—Leaves are tightly held in open or closed position by pneumatically actuated clamps. A linkage-actuated C-clamp holds the leaves against the nacelle. In the other position, clamping is accomplished by a notched sliding block.



Unique Valves Direct Compressor Airflow

AIRFLOW through a series of four axial flow compressors used with a supersonic wind tunnel is directed by three unique iris valves. The valves are made up of a number of overlapping vanes or leaves and may be used either to direct airflow into an annular bypass duct around one or more of the four compressors or into the next compressor in series tandem, Fig. 1. When airflow is diverted around a compressor, its shaft disconnect coupling is opened to conserve power. Total connected power exceeds 200,000 hp.

Valve leaves are moved from open to closed position by hydraulic cylinders, Fig. 2, coupled to the leaves by airfoil section rods. Cylinders are mounted on structure of tunnel shell. Complete closure and positive retention of the leaves in both open and closed positions is provided by pneumatically operated clamping devices, Fig. 3. The first iris valve is 18 ft long and approximately 29 ft in diameter. Individual leaves vary from 48 to 50 in. in width and are about 10¾ in. deep except at the seat end where thickness is 1½ in. Under maximum loading conditions, total uniform air load per leaf in valve No. 1 is 180,000 lb.

Silicone rubber seals are used on edges and seating ends of the leaves to keep leakage to a minimum. Flat laminated spring steel seals are used at hinge ends. These materials were selected for their ability to perform satisfactorily with air stream temperatures of 100 to 700 F. Bearing material selection was also influenced by operating temperature range as well as the fact that there could be no lubricant in the air stream. Leaf hinge pins are of heat-treated alloy steel and operate in bronze bushings having graphite inserts which provide the necessary lubrication. Crosshead bearings for connecting leaves and operating cylinders are of similar construction.—C. HORACK, *Mechanical Engineering, Pacific Coast Mfg. Plant, Westinghouse Electric Corp., Sunnyvale, Calif.*

Preferred Gear Sizes

Tables of dimensions for precision gears based on a preferred series of diametral pitches

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FLEXIBILITY in design, with minimum tooling costs, can be a particularly tough problem when one-shot or small production runs are frequent.

Gearing, specifically small or precision gearing, is a good example. Conceivably a draftsman or designer could choose any diametral pitch upon which to base the design of a gear set. If unchecked, he could require the shop to maintain gear-cutting tools for all the various pitches that have been or might be called out on a drawing.

It is possible, however, by setting up a preferred series of diametral pitch sizes, such as 24, 32, 48, 64, 96 and 120, to allow the designer an almost unlimited number of gear sizes and combinations and yet require the shop to stock only six sizes of cutting tools and inspection equipment. This is a real advantage in cutting costs.

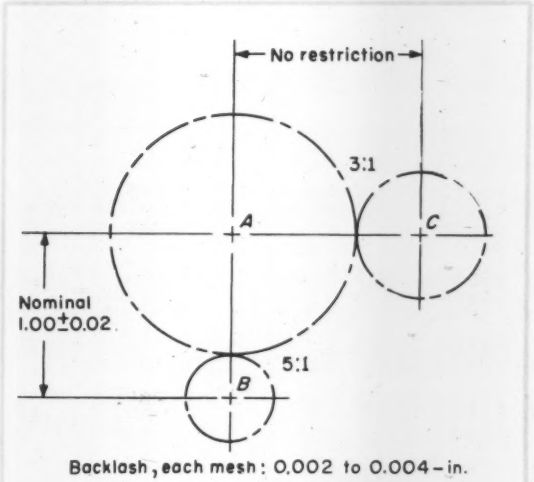

Fig. 1 — Design requirements for example problem.

These suggested pitches have actually been selected at the Westinghouse Air Arm Div. as a preferred series. Advocates of preferred numbers may be dismayed to observe that the 24-32-48-64-96-120 series departs substantially from a standard progression. However, it does have the practical advantage of being a selection from the diametral pitches offered by commercial sources of precision gearing. Hence, ready availability of gears or tooling is assured.

Another advantage of setting up a series of preferred diametral pitches or gear designs is that tables can be prepared listing basic gear dimensions and eliminating many calculations. Tables 1, 2 and 3 are examples of how this information can be presented.

Table 1 establishes the basic dimensions of 20-deg fine-pitch involute external gears with 7 to 120 teeth. For each diametral pitch the pitch diameter, the outside diameter and the nominal measurement over pins are given. In addition, the K_M value is listed to allow quick calculation of the change in nominal measurement over pins to reflect backlash.

For gears with 7 to 17 teeth complete dimensions are not given. The reason for the omissions is that in the 20-deg system pinions with less than 18 teeth require special considerations to avoid undercutting or interference. The designer is referred to American Standard ASA B6.7-1956 (AGMA 207.04) for design information.

Table 2 lists the standard center distance between two gears for a given diametral pitch and total teeth in the gear mesh. Values are given for meshes with 36 to 240 teeth.

Table 3 lists the pin diameter to be used with each diametral pitch to check measurement over pins.

The value of these tables is that they eliminate trial and error for the most part in arriving at the best arrangement for a particular gear set.

Example: Design a set of three gears in the 20-deg fine-pitch involute system within the dimen-

Table 1—Basic Gear Dimensions—20-Deg. Fine-Pitch Involute System

Teeth	24 DP			32 DP			48 DP			64 DP			96 DP			120 DP			K_M	Teeth
	PD	OD	M	PD	OD	M	PD	OD	M	PD	OD	M	PD	OD	M	PD	OD	M		
7	0.2917			0.2188			0.1458			0.1094			0.0729			0.0583				
8	0.3333			0.2500			0.1667			0.1250			0.0833			0.0667				
9	0.3750			0.2813			0.1875			0.1406			0.0938			0.0750				
10	0.4167			0.3125			0.2083			0.1563			0.1042			0.0833				
11	0.4583			0.3438			0.2292			0.1719			0.1146			0.0917				
12	0.5000			0.3750			0.2500			0.1875			0.1250			0.1000				
13	0.5417			0.4063			0.2708			0.2031			0.1354			0.1083				
14	0.5833			0.4375			0.2917			0.2188			0.1458			0.1167				
15	0.6250			0.4688			0.3125			0.2344			0.1563			0.1250				
16	0.6667			0.5000			0.3333			0.2500			0.1667			0.1333				
17	0.7083			0.5313			0.3542			0.2656			0.1771			0.1417				
18	0.7500	0.8333	0.8493	0.5625	0.6250	0.6370	0.3750	0.4167	0.4247	0.2813	0.3125	0.3185	0.1875	0.2083	0.2123	0.1500	0.1667	0.1699	2.23	18
19	0.7917	0.8750	0.8883	0.5938	0.6563	0.6663	0.3958	0.4375	0.4442	0.2969	0.3281	0.3331	0.1979	0.2188	0.2221	0.1583	0.1750	0.1777	2.25	19
20	0.8333	0.9167	0.9329	0.6250	0.6875	0.6997	0.4167	0.4583	0.4665	0.3125	0.3438	0.3498	0.2083	0.2292	0.2332	0.1667	0.1833	0.1866	2.26	20
21	0.8750	0.9583	0.9722	0.6563	0.7188	0.7291	0.4375	0.4792	0.4861	0.3281	0.3594	0.3646	0.2188	0.2396	0.2430	0.1750	0.1917	0.1944	2.28	21
22	0.9167	1.0000	1.0165	0.6875	0.7500	0.7624	0.4583	0.5000	0.5082	0.3438	0.3750	0.3812	0.2292	0.2500	0.2541	0.1833	0.2000	0.2033	2.29	22
23	0.9583	1.0417	1.0559	0.7188	0.7813	0.7919	0.4792	0.5208	0.5280	0.3594	0.3906	0.3960	0.2396	0.2604	0.2640	0.1917	0.2083	0.2112	2.30	23
24	1.0000	1.0833	1.1000	0.7500	0.8125	0.8250	0.5000	0.5417	0.5500	0.3750	0.4063	0.4125	0.2500	0.2708	0.2750	0.2000	0.2167	0.2200	2.32	24
25	1.0417	1.1250	1.1396	0.7813	0.8438	0.8547	0.5208	0.5625	0.5698	0.3906	0.4219	0.4274	0.2604	0.2813	0.2849	0.2083	0.2250	0.2279	2.33	25
26	1.0833	1.1667	1.1835	0.8125	0.8750	0.8876	0.5417	0.5833	0.5917	0.4063	0.4375	0.4438	0.2708	0.2917	0.2959	0.2167	0.2333	0.2367	2.34	26
27	1.1250	1.2083	1.2233	0.8438	0.9063	0.9175	0.5625	0.6042	0.6116	0.4219	0.4531	0.4587	0.2813	0.3021	0.3058	0.2250	0.2417	0.2447	2.35	27
28	1.1667	1.2500	1.2670	0.8750	0.9375	0.9502	0.5833	0.6250	0.6335	0.4375	0.4688	0.4751	0.2917	0.3125	0.3167	0.2333	0.2500	0.2534	2.36	28
29	1.2083	1.2917	1.3069	0.9063	0.9688	0.9802	0.6042	0.6458	0.6534	0.4531	0.4844	0.4901	0.3021	0.3229	0.3267	0.2417	0.2583	0.2614	2.37	29
30	1.2500	1.3333	1.3504	0.9375	1.0000	1.0128	0.6250	0.6667	0.6752	0.4688	0.5000	0.5064	0.3125	0.3333	0.3376	0.2500	0.2667	0.2701	2.38	30
31	1.2917	1.3750	1.3905	0.9688	1.0313	1.0428	0.6458	0.6875	0.6952	0.4844	0.5156	0.5214	0.3229	0.3438	0.3476	0.2583	0.2750	0.2781	2.39	31
32	1.3333	1.4167	1.4339	1.0000	1.0625	1.0754	0.6667	0.7083	0.7169	0.5000	0.5313	0.5377	0.3333	0.3542	0.3585	0.2667	0.2833	0.2868	2.40	32
33	1.3750	1.4583	1.4740	1.0313	1.0938	1.1055	0.6875	0.7292	0.7370	0.5156	0.5469	0.5528	0.3438	0.3646	0.3685	0.2750	0.2917	0.2948	2.41	33
34	1.4167	1.5000	1.5173	1.0625	1.1250	1.1380	0.7083	0.7500	0.7587	0.5313	0.5625	0.5690	0.3542	0.3750	0.3793	0.2833	0.3000	0.3035	2.41	34
35	1.4583	1.5417	1.5575	1.0938	1.1563	1.1681	0.7292	0.7708	0.7788	0.5469	0.5781	0.5841	0.3646	0.3854	0.3894	0.2917	0.3083	0.3115	2.42	35
36	1.5000	1.5833	1.6007	1.1250	1.1875	1.2006	0.7500	0.7917	0.8004	0.5625	0.5938	0.6003	0.3750	0.3958	0.4002	0.3000	0.3167	0.3201	2.43	36
37	1.5417	1.6250	1.6410	1.1563	1.2188	1.2308	0.7708	0.8125	0.8205	0.5781	0.6094	0.6154	0.3854	0.4063	0.4103	0.3083	0.3250	0.3282	2.43	37
38	1.5833	1.6667	1.6842	1.1875	1.2500	1.2631	0.7917	0.8333	0.8421	0.5938	0.6250	0.6316	0.3958	0.4167	0.4210	0.3167	0.3333	0.3368	2.44	38
39	1.6250	1.7083	1.7245	1.2188	1.2813	1.2934	0.8125	0.8542	0.8623	0.6094	0.6406	0.6467	0.4063	0.4271	0.4311	0.3250	0.3417	0.3449	2.45	39
40	1.6667	1.7500	1.7676	1.2500	1.3125	1.3257	0.8333	0.8750	0.8838	0.6250	0.6563	0.6628	0.4167	0.4375	0.4419	0.3333	0.3500	0.3535	2.45	40
41	1.7083	1.7917	1.8080	1.2813	1.3438	1.3560	0.8542	0.8958	0.9040	0.6406	0.6719	0.6780	0.4271	0.4479	0.4520	0.3417	0.3583	0.3616	2.46	41
42	1.7500	1.8333	1.8510	1.3125	1.3750	1.3882	0.8750	0.9167	0.9255	0.6563	0.6875	0.6941	0.4375	0.4583	0.4627	0.3500	0.3667	0.3702	2.46	42
43	1.7917	1.8750	1.8915	1.3438	1.4063	1.4186	0.8958	0.9375	0.9457	0.6719	0.7031	0.7093	0.4479	0.4688	0.4729	0.3583	0.3750	0.3783	2.47	43
44	1.8333	1.9167	1.9344	1.3750	1.4375	1.4508	0.9167	0.9583	0.9672	0.6875	0.7188	0.7254	0.4583	0.4792	0.4836	0.3667	0.3833	0.3869	2.47	44
45	1.8750	1.9583	1.9749	1.4063	1.4688	1.4812	0.9375	0.9792	0.9875	0.7031	0.7344	0.7406	0.4688	0.4896	0.4937	0.3750	0.3917	0.3950	2.48	45
46	1.9167	2.0000	2.0178	1.4375	1.5000	1.5133	0.9583	1.0000	1.0089	0.7188	0.7500	0.7567	0.4792	0.5000	0.5044	0.3833	0.4000	0.4036	2.48	46
47	1.9583	2.0417	2.0584	1.4688	1.5313	1.5438	0.9792	1.0208	1.0292	0.7344	0.7656	0.7719	0.4896	0.5104	0.5146	0.3917	0.4083	0.4117	2.49	47
48	2.0000	2.0833	2.1012	1.5000	1.5625	1.5759	1.0000	1.0417	1.0506	0.7500	0.7813	0.7879	0.5000	0.5208	0.5253	0.4000	0.4167	0.4202	2.49	48
49	2.0417	2.1250	2.1418	1.5313	1.5938	1.6063	1.0208	1.0625	1.0709	0.7656	0.7969	0.8032	0.5104	0.5313	0.5354	0.4083	0.4250	0.4284	2.50	49
50	2.0833	2.1667	2.1846	1.5625	1.6250	1.6384	1.0417	1.0833	1.0923	0.7813	0.8125	0.8192	0.5208	0.5417	0.5461	0.4167	0.4333	0.4369	2.50	50
51	2.1250	2.2083	2.2252	1.5938	1.6563	1.6689	1.0625	1.1042	1.1126	0.7969	0.8281	0.8345	0.5313	0.5521	0.5563	0.4250	0.4417	0.4450	2.50	51
52	2.1667	2.2500	2.2679	1.6250	1.6875	1.7010	1.0833	1.1250	1.1340	0.8125	0.8438	0.8505	0.5417	0.5625	0.5670	0.4333	0.4500	0.4536	2.51	52
53	2.2083	2.2917	2.3086	1.6563	1.7188	1.7315	1.1042	1.1458	1.1543	0.8281	0.8594	0.8657	0.5521	0.5729	0.5772	0.4417	0.4583	0.4617	2.51	53
54	2.2500	2.3333	2.3513	1.6875	1.7500	1.7635	1.1250	1.1667	1.1757	0.8438	0.8750	0.8817	0.5625	0.5833	0.5878	0.4500	0.4667	0.4703	2.52	54
55	2.2917	2.3750	2.3921	1.7188	1.7813	1.7940	1.1458	1.1875	1.1960	0.8594	0.8906	0.8970	0.5729	0.5938	0.5980	0.4583	0.4750	0.4784	2.52	55
56	2.3333	2.4167	2.4347	1.7500	1.8125	1.8260	1.1667	1.2083	1.2173	0.8750	0.9063	0.9130	0.5833	0.6042	0.6087	0.4667	0.4833	0.4869	2.52	56
57	2.3750	2.4583	2.4755	1.7813	1.8438	1.8566	1.1875	1.2292	1.2377	0.8905	0.9219	0.9283	0.5938	0.6146	0.6189	0.4750	0.4917	0.4951	2.53	57
58	2.4167	2.5000	2.5181	1.8125	1.8750	1.8885	1.2083	1.2500	1.2590	0.9063	0.9375	0.9443	0.6042	0.6250	0.6295	0.4833	0.5000	0.5036	2.53	58
59	2.4583	2.5417	2.5589	1.8438	1.9063	1.9192	1.2292	1.2708	1.2794	0.9219	0.9531	0.9596	0.6146	0.6354	0.6397	0.4917	0.5083	0.5118	2.53	59
60	2.5000	2.5833	2.6014	1.8750	1.9375	1.9511	1.2500	1.2917	1.3007	0.9375	0.9688	0.9755	0.6250	0.6458	0.6504	0.5000	0.5167	0.5203	2.53	60
61	2.5417	2.6250	2.6423	1.9063	1.9688	1.9817	1.2708	1.3125	1.3211	0.9531	0.9844	0.9909	0.6354	0.6563	0.6606	0.5083	0.5250	0.5285	2.54	61
62	2.5833	2.6667	2.6848	1.9375	2.0000	2.0136	1.2917	1.3333	1.3424	0.9688	1.0000	1.0068	0.6458	0.6667	0.6712	0.5167	0.5333	0.5370	2.54	62
63	2.6250	2.7083	2.7257	1.9688	2.0313	2.0442	1.3125	1.3542	1.3628	0.9844	1.0156	1.0221	0.6563	0.6771	0.6814	0.5250	0.5417	0.5451	2.54	63
64	2.6667	2.7500	2.7682	2.0000	2.0625	2.0761	1.3333	1.3750	1.3841	1.0000	1.0313	1.0381	0.6667	0.6875	0.6920	0.5333	0.5500	0.5536	2.55	64
65	2.7083	2.7917	2.8091	2.0313	2.0938	2.1068	1.3542	1.3958	1.4045	1.0156	1.0469	1.0534	0.6771	0.6979	0.7023	0.5417	0.5583	0.5618	2.55	65

Teeth	24 DP PD	24 DP OD	24 DP M	32 DP PD	32 DP OD	32 DP M	48 DP PD	48 DP OD	48 DP M	64 DP PD	64 DP OD	64 DP M	96 DP PD	96 DP OD	96 DP M	120 DP PD	120 DP OD	120 DP M	K_M	Teeth
66	2.7500	2.8333	2.8515	2.0625	2.1250	2.1387	1.3750	1.4167	1.4258	1.0313	1.0625	1.0693	0.6875	0.7083	0.7129	0.5500	0.5667	0.5703	2.55	66
67	2.7917	2.8750	2.8924	2.0938	2.1563	2.1693	1.3958	1.4375	1.4462	1.0469	1.0781	1.0847	0.6979	0.7188	0.7231	0.5583	0.5750	0.5785	2.55	67
68	2.8333	2.9167	2.9349	2.1250	2.1875	2.2012	1.4167	1.4583	1.4675	1.0625	1.0938	1.1006	0.7083	0.7292	0.7337	0.5667	0.5833	0.5870	2.56	68
69	2.8750	2.9583	2.9773	2.1563	2.2188	2.2319	1.4375	1.4792	1.4879	1.0781	1.1094	1.1159	0.7188	0.7396	0.7440	0.5750	0.5917	0.5952	2.56	69
70	2.9167	3.0000	3.0183	2.1875	2.2500	2.2637	1.4583	1.5000	1.5091	1.0938	1.1250	1.1318	0.7292	0.7500	0.7546	0.5833	0.6000	0.6037	2.56	70
71	2.9583	3.0417	3.0592	2.2188	2.2813	2.2944	1.4792	1.5208	1.5296	1.1094	1.1406	1.1472	0.7396	0.7604	0.7648	0.5917	0.6083	0.6118	2.56	71
72	3.0000	3.0833	3.1016	2.2500	2.3125	2.3262	1.5000	1.5417	1.5508	1.1250	1.1563	1.1631	0.7500	0.7708	0.7754	0.6000	0.6167	0.6203	2.57	72
73	3.0417	3.1250	3.1426	2.2813	2.3438	2.3569	1.5208	1.5625	1.5713	1.1406	1.1719	1.1785	0.7604	0.7813	0.7856	0.6083	0.6250	0.6285	2.57	73
74	3.0833	3.1667	3.1850	2.3125	2.3750	2.3887	1.5417	1.5833	1.5925	1.1563	1.1875	1.1944	0.7708	0.7917	0.7962	0.6167	0.6333	0.6370	2.57	74
75	3.1250	3.2083	3.2260	2.3438	2.4063	2.4195	1.5625	1.6042	1.6130	1.1719	1.2031	1.2097	0.7813	0.8021	0.8065	0.6250	0.6417	0.6452	2.57	75
76	3.1667	3.2500	3.2683	2.3750	2.4375	2.4513	1.5833	1.6250	1.6342	1.1875	1.2188	1.2256	0.7917	0.8125	0.8171	0.6333	0.6500	0.6537	2.57	76
77	3.2083	3.2917	3.3093	2.4063	2.4688	2.4820	1.6042	1.6458	1.6547	1.2031	1.2344	1.2410	0.8021	0.8229	0.8273	0.6417	0.6583	0.6619	2.58	77
78	3.2500	3.3333	3.3517	2.4375	2.5000	2.5138	1.6250	1.6667	1.6759	1.2188	1.2500	1.2569	0.8125	0.8333	0.8379	0.6500	0.6667	0.6703	2.58	78
79	3.2917	3.3750	3.3927	2.4688	2.5313	2.5445	1.6458	1.6875	1.6964	1.2344	1.2656	1.2723	0.8229	0.8438	0.8482	0.6583	0.6750	0.6785	2.58	79
80	3.3333	3.4167	3.4351	2.5000	2.5625	2.5763	1.6667	1.7083	1.7175	1.2500	1.2813	1.2881	0.8333	0.8542	0.8588	0.6667	0.6833	0.6870	2.58	80
81	3.3750	3.4583	3.4761	2.5313	2.5938	2.6071	1.6875	1.7292	1.7380	1.2656	1.2969	1.3035	0.8438	0.8646	0.8690	0.6750	0.6917	0.6952	2.58	81
82	3.4167	3.5000	3.5184	2.5625	2.6250	2.6388	1.7083	1.7500	1.7592	1.2813	1.3125	1.3194	0.8542	0.8750	0.8796	0.6833	0.7000	0.7037	2.58	82
83	3.4583	3.5417	3.5595	2.5938	2.6563	2.6696	1.7292	1.7708	1.7797	1.2969	1.3281	1.3348	0.8646	0.8854	0.8899	0.6917	0.7083	0.7119	2.59	83
84	3.5000	3.5833	3.6018	2.6250	2.6875	2.7013	1.7500	1.7917	1.8009	1.3125	1.3438	1.3507	0.8750	0.8958	0.9004	0.7000	0.7167	0.7204	2.59	84
85	3.5417	3.6250	3.6428	2.6563	2.7188	2.7321	1.7708	1.8125	1.8214	1.3281	1.3594	1.3661	0.8854	0.9063	0.9107	0.7083	0.7250	0.7286	2.59	85
86	3.5833	3.6667	3.6851	2.6875	2.7500	2.7638	1.7917	1.8333	1.8426	1.3438	1.3750	1.3819	0.8958	0.9167	0.9213	0.7167	0.7333	0.7370	2.59	86
87	3.6250	3.7083	3.7262	2.7188	2.7813	2.7946	1.8125	1.8542	1.8631	1.3594	1.3906	1.3973	0.9063	0.9271	0.9315	0.7250	0.7417	0.7452	2.59	87
88	3.6667	3.7500	3.7685	2.7500	2.8125	2.8264	1.8333	1.8750	1.8842	1.3750	1.4063	1.4132	0.9167	0.9375	0.9421	0.7333	0.7500	0.7537	2.59	88
89	3.7083	3.7917	3.8096	2.7813	2.8438	2.8572	1.8542	1.8958	1.9048	1.3906	1.4219	1.4286	0.9271	0.9479	0.9524	0.7417	0.7583	0.7619	2.60	89
90	3.7500	3.8333	3.8518	2.8125	2.8750	2.8889	1.8750	1.9167	1.9259	1.4063	1.4375	1.4444	0.9375	0.9583	0.9630	0.7500	0.7667	0.7704	2.60	90
91	3.7917	3.8750	3.8929	2.8438	2.9063	2.9197	1.8958	1.9375	1.9465	1.4219	1.4531	1.4598	0.9479	0.9688	0.9732	0.7583	0.7750	0.7786	2.60	91
92	3.8333	3.9167	3.9352	2.8750	2.9375	2.9514	1.9167	1.9583	1.9676	1.4375	1.4688	1.4757	0.9583	0.9792	0.9838	0.7667	0.7833	0.7870	2.60	92
93	3.8750	3.9583	3.9763	2.9063	2.9688	2.9822	1.9375	1.9792	1.9881	1.4531	1.4844	1.4911	0.9688	0.9896	0.9941	0.7750	0.7917	0.7953	2.60	93
94	3.9167	4.0000	4.0185	2.9375	3.0000	3.0139	1.9583	2.0000	2.0093	1.4688	1.5000	1.5069	0.9792	1.0000	1.0046	0.7833	0.8000	0.8037	2.60	94
95	3.9583	4.0417	4.0597	2.9688	3.0313	3.0447	1.9792	2.0208	2.0298	1.4844	1.5156	1.5224	0.9896	1.0104	1.0149	0.7917	0.8083	0.8119	2.60	95
96	4.0000	4.0833	4.1019	3.0000	3.0625	3.0764	2.0000	2.0417	2.0509	1.5000	1.5313	1.5382	1.0000	1.0208	1.0255	0.8000	0.8167	0.8204	2.61	96
97	4.0417	4.1250	4.1430	3.0313	3.0938	3.1073	2.0208	2.0625	2.0715	1.5156	1.5469	1.5536	1.0104	1.0313	1.0358	0.8083	0.8250	0.8286	2.61	97
98	4.0833	4.1667	4.1852	3.0625	3.1250	3.1389	2.0417	2.0833	2.0926	1.5313	1.5625	1.5695	1.0208	1.0417	1.0463	0.8167	0.8333	0.8370	2.61	98
99	4.1250	4.2083	4.2264	3.0938	3.1563	3.1698	2.0625	2.1042	2.1132	1.5469	1.5781	1.5849	1.0313	1.0521	1.0566	0.8250	0.8417	0.8453	2.61	99
100	4.1667	4.2500	4.2686	3.1250	3.1875	3.2014	2.0833	2.1250	2.1343	1.5625	1.5938	1.6007	1.0417	1.0625	1.0671	0.8333	0.8500	0.8537	2.61	100
101	4.2083	4.2917	4.3097	3.1563	3.2188	3.2323	2.1042	2.1458	2.1549	1.5781	1.6094	1.6161	1.0521	1.0729	1.0774	0.8417	0.8583	0.8619	2.61	101
102	4.2500	4.3333	4.3519	3.1875	3.2500	3.2639	2.1250	2.1667	2.1760	1.5938	1.6250	1.6320	1.0625	1.0833	1.0880	0.8500	0.8667	0.8704	2.61	102
103	4.2917	4.3750	4.3931	3.2188	3.2813	3.2948	2.1458	2.1875	2.1965	1.6094	1.6406	1.6474	1.0729	1.0938	1.0983	0.8583	0.8750	0.8786	2.61	103
104	4.3333	4.4167	4.4353	3.2500	3.3125	3.3264	2.1667	2.2083	2.2176	1.6250	1.6563	1.6632	1.0833	1.1042	1.1088	0.8667	0.8833	0.8871	2.62	104
105	4.3750	4.4583	4.4764	3.2813	3.3438	3.3573	2.1875	2.2292	2.2382	1.6406	1.6719	1.6787	1.0938	1.1146	1.1191	0.8750	0.8917	0.8953	2.62	105
106	4.4167	4.5000	4.5186	3.3125	3.3750	3.3890	2.2083	2.2500	2.2593	1.6563	1.6875	1.6945	1.1042	1.1250	1.1297	0.8833	0.9000	0.9037	2.62	106
107	4.4583	4.5417	4.5598	3.3438	3.4063	3.4199	2.2292	2.2708	2.2799	1.6719	1.7031	1.7099	1.1146	1.1354	1.1400	0.8917	0.9083	0.9120	2.62	107
108	4.5000	4.5833	4.6020	3.3750	3.4375	3.4515	2.2500	2.2917	2.3010	1.6875	1.7188	1.7257	1.1250	1.1458	1.1505	0.9000	0.9167	0.9204	2.62	108
109	4.5417	4.6250	4.6432	3.4063	3.4688	3.4824	2.2708	2.3125	2.3216	1.7031	1.7344	1.7412	1.1354	1.1563	1.1608	0.9083	0.9250	0.9286	2.62	109
110	4.5833	4.6667	4.6853	3.4375	3.5000	3.5140	2.2917	2.3333	2.3427	1.7188	1.7500	1.7570	1.1458	1.1667	1.1713	0.9167	0.9333	0.9371	2.62	110
111	4.6250	4.7083	4.7265	3.4688	3.5313	3.5449	2.3125	2.3542	2.3633	1.7344	1.7656	1.7724	1.1563	1.1771	1.1816	0.9250	0.9417	0.9453	2.62	111
112	4.6667	4.7500	4.7686	3.5000	3.5625	3.5765	2.3333	2.3750	2.3843	1.7500	1.7813	1.7882	1.1667	1.1875	1.1922	0.9333	0.9500	0.9537	2.62	112
113	4.7083	4.7917	4.8099	3.5313	3.5938	3.6074	2.3542	2.3958	2.4049	1.7656	1.7969	1.8037	1.1771	1.1979	1.2025	0.9417	0.9583	0.9620	2.63	113
114	4.7500	4.8333	4.8520	3.5625	3.6250	3.6390	2.3750	2.4167	2.4260	1.7813	1.8125	1.8195	1.1875	1.2083	1.2130	0.9500	0.9667	0.9704	2.63	114
115	4.7917	4.8750	4.8932	3.5938	3.6563	3.6699	2.3958	2.4375	2.4466	1.7969	1.8281	1.8350	1.1979	1.2188	1.2233	0.9583	0.9750	0.9786	2.63	115
116	4.8333	4.9167	4.9353	3.6250	3.6875	3.7015	2.4167	2.4583	2.4677	1.8125	1.8438	1.8508	1.2083	1.2292	1.2338	0.9667	0.9833	0.9871	2.63	116
117	4.8750	4.9583	4.9766	3.6563	3.7188	3.7324	2.4375	2.4792	2.4883	1.8281	1.8594	1.8662	1.2188	1.2396	1.2441	0.9750	0.9917	0.9953	2.63	117
118	4.9167	5.0000	5.0187	3.6875	3.7500	3.7640	2.4583	2.5000	2.5093	1.8438	1.8750	1.8820	1.2292	1.2500	1.2547	0.9833	1.0000	1.0037	2.63	118
119	4.9583	5.0417	5.0599	3.7188	3.7813	3.7949	2.4792	2.5208	2.5300	1.8594	1.8906	1.8975	1.2396	1.2604	1.2650	0.9917	1.0083	1.0120	2.63	119
120	5.0000	5.0833	5.1020	3.7500	3.8125	3.8265	2.5000	2.5417	2.5510	1.8750	1.9063	1.9133	1.2500	1.2708	1.2755	1.0000	1.0167	1.0204	2.63	120

Nomenclature: PD = pitch diameter, in.; OD = outside diameter, in.; M = measurement over pins, in.;
K_M = (change in measurement over pins) ÷ (change in circular thickness).

Table 2—Standard Center Distance Between Two Gears

Teeth	24 DP	32 DP	48 DP	64 DP	96 DP	120 DP
36	0.7500	0.5625	0.3750	0.2813	0.1875	0.1500
37	0.7708	0.5781	0.3854	0.2891	0.1927	0.1542
38	0.7917	0.5938	0.3958	0.2969	0.1979	0.1583
39	0.8125	0.6094	0.4063	0.3047	0.2031	0.1625
40	0.8333	0.6250	0.4167	0.3125	0.2083	0.1667
41	0.8542	0.6406	0.4271	0.3203	0.2135	0.1708
42	0.8750	0.6563	0.4375	0.3281	0.2188	0.1750
43	0.8958	0.6719	0.4479	0.3359	0.2240	0.1792
44	0.9167	0.6875	0.4583	0.3438	0.2292	0.1833
45	0.9375	0.7031	0.4688	0.3516	0.2344	0.1875
46	0.9583	0.7188	0.4792	0.3594	0.2396	0.1917
47	0.9792	0.7344	0.4896	0.3672	0.2448	0.1958
48	1.0000	0.7500	0.5000	0.3750	0.2500	0.2000
49	1.0208	0.7656	0.5104	0.3828	0.2552	0.2042
50	1.0417	0.7813	0.5208	0.3906	0.2604	0.2083
51	1.0625	0.7969	0.5313	0.3984	0.2656	0.2125
52	1.0833	0.8125	0.5417	0.4063	0.2708	0.2167
53	1.1042	0.8281	0.5521	0.4141	0.2760	0.2208
54	1.1250	0.8438	0.5625	0.4219	0.2813	0.2250
55	1.1458	0.8594	0.5729	0.4297	0.2865	0.2292
56	1.1667	0.8750	0.5833	0.4375	0.2917	0.2333
57	1.1875	0.8906	0.5938	0.4453	0.2969	0.2375
58	1.2083	0.9063	0.6042	0.4531	0.3021	0.2417
59	1.2292	0.9219	0.6146	0.4609	0.3073	0.2458
60	1.2500	0.9375	0.6250	0.4688	0.3125	0.2500
61	1.2708	0.9531	0.6354	0.4766	0.3177	0.2542
62	1.2917	0.9688	0.6458	0.4844	0.3229	0.2583
63	1.3125	0.9844	0.6563	0.4922	0.3281	0.2625
64	1.3333	1.0000	0.6667	0.5000	0.3333	0.2667
65	1.3542	1.0156	0.6771	0.5078	0.3385	0.2708
66	1.3750	1.0313	0.6875	0.5156	0.3438	0.2750
67	1.3958	1.0469	0.6979	0.5234	0.3490	0.2792
68	1.4167	1.0625	0.7083	0.5313	0.3542	0.2833
69	1.4375	1.0781	0.7188	0.5391	0.3594	0.2875
70	1.4583	1.0938	0.7292	0.5469	0.3646	0.2917
71	1.4792	1.1094	0.7396	0.5547	0.3698	0.2958
72	1.5000	1.1250	0.7500	0.5625	0.3750	0.3000
73	1.5208	1.1406	0.7604	0.5703	0.3802	0.3042
74	1.5417	1.1563	0.7708	0.5781	0.3854	0.3083
75	1.5625	1.1719	0.7813	0.5859	0.3906	0.3125
76	1.5833	1.1875	0.7917	0.5938	0.3958	0.3167
77	1.6042	1.2031	0.8021	0.6016	0.4010	0.3208
78	1.6250	1.2188	0.8125	0.6094	0.4063	0.3250
79	1.6458	1.2344	0.8229	0.6172	0.4115	0.3292
80	1.6667	1.2500	0.8333	0.6250	0.4167	0.3333
81	1.6875	1.2656	0.8438	0.6328	0.4219	0.3375
82	1.7083	1.2813	0.8542	0.6406	0.4271	0.3417
83	1.7292	1.2969	0.8646	0.6484	0.4323	0.3458
84	1.7500	1.3125	0.8750	0.6563	0.4375	0.3500
85	1.7708	1.3281	0.8854	0.6641	0.4427	0.3542
86	1.7917	1.3438	0.8958	0.6719	0.4479	0.3583
87	1.8125	1.3594	0.9063	0.6797	0.4531	0.3625
88	1.8333	1.3750	0.9167	0.6875	0.4583	0.3667
89	1.8542	1.3906	0.9271	0.6953	0.4635	0.3708
90	1.8750	1.4063	0.9375	0.7031	0.4688	0.3750
91	1.8958	1.4219	0.9479	0.7109	0.4740	0.3792
92	1.9167	1.4375	0.9583	0.7188	0.4792	0.3833
93	1.9375	1.4531	0.9688	0.7266	0.4844	0.3875
94	1.9583	1.4688	0.9792	0.7344	0.4896	0.3917
95	1.9792	1.4844	0.9896	0.7422	0.4948	0.3958
96	2.0000	1.5000	1.0000	0.7500	0.5000	0.4000
97	2.0208	1.5156	1.0104	0.7578	0.5052	0.4042
98	2.0417	1.5313	1.0208	0.7656	0.5104	0.4083
99	2.0625	1.5469	1.0313	0.7734	0.5156	0.4125
100	2.0833	1.5625	1.0417	0.7813	0.5208	0.4167
101	2.1042	1.5781	1.0521	0.7891	0.5260	0.4208
102	2.1250	1.5938	1.0625	0.7969	0.5313	0.4250
103	2.1458	1.6094	1.0729	0.8047	0.5365	0.4292
104	2.1667	1.6250	1.0833	0.8125	0.5417	0.4333
105	2.1875	1.6406	1.0938	0.8203	0.5469	0.4375
106	2.2083	1.6563	1.1042	0.8281	0.5521	0.4417
107	2.2292	1.6719	1.1146	0.8359	0.5573	0.4458
108	2.2500	1.6875	1.1250	0.8438	0.5625	0.4500
109	2.2708	1.7031	1.1354	0.8516	0.5677	0.4542
110	2.2917	1.7188	1.1458	0.8594	0.5729	0.4583
111	2.3125	1.7344	1.1563	0.8672	0.5781	0.4625
112	2.3333	1.7500	1.1667	0.8750	0.5833	0.4667
113	2.3542	1.7656	1.1771	0.8828	0.5885	0.4708
114	2.3750	1.7813	1.1875	0.8906	0.5938	0.4750
115	2.3958	1.7969	1.1979	0.8984	0.5990	0.4792
116	2.4167	1.8125	1.2083	0.9063	0.6042	0.4833
117	2.4375	1.8281	1.2188	0.9141	0.6094	0.4875
118	2.4583	1.8438	1.2292	0.9219	0.6146	0.4917
119	2.4792	1.8594	1.2396	0.9297	0.6198	0.4958
120	2.5000	1.8750	1.2500	0.9375	0.6250	0.5000
121	2.5208	1.8906	1.2604	0.9453	0.6302	0.5042
122	2.5417	1.9063	1.2708	0.9531	0.6354	0.5083
123	2.5625	1.9219	1.2813	0.9609	0.6406	0.5125
124	2.5833	1.9375	1.2917	0.9688	0.6458	0.5167
125	2.6042	1.9531	1.3021	0.9766	0.6510	0.5208
126	2.6250	1.9688	1.3125	0.9844	0.6563	0.5250
127	2.6458	1.9844	1.3229	0.9922	0.6615	0.5292
128	2.6667	2.0000	1.3333	1.0000	0.6667	0.5333
129	2.6875	2.0156	1.3438	1.0078	0.6719	0.5375
130	2.7083	2.0313	1.3542	1.0156	0.6771	0.5417
131	2.7292	2.0469	1.3646	1.0234	0.6823	0.5458
132	2.7500	2.0625	1.3750	1.0313	0.6875	0.5500
133	2.7708	2.0781	1.3854	1.0391	0.6927	0.5542
134	2.7917	2.0938	1.3958	1.0469	0.6979	0.5583
135	2.8125	2.1094	1.4063	1.0547	0.7031	0.5625
136	2.8333	2.1250	1.4167	1.0625	0.7083	0.5667
137	2.8542	2.1406	1.4271	1.0703	0.7135	0.5708
138	2.8750	2.1563	1.4375	1.0781	0.7188	0.5750
139	2.8958	2.1719	1.4479	1.0859	0.7240	0.5792
140	2.9167	2.1875	1.4583	1.0938	0.7292	0.5833
141	2.9375	2.2031	1.4688	1.1016	0.7344	0.5875
142	2.9583	2.2188	1.4792	1.1094	0.7396	0.5917
143	2.9792	2.2344	1.4896	1.1172	0.7448	0.5958
144	3.0000	2.2500	1.5000	1.1250	0.7500	0.6000
145	3.0208	2.2656	1.5104	1.1328	0.7552	0.6042
146	3.0417	2.2813	1.5208	1.1406	0.7604	0.6083
147	3.0625	2.2969	1.5313	1.1484	0.7656	0.6125
148	3.0833	2.3125	1.5417	1.1563	0.7708	0.6167
149	3.1042	2.3281	1.5521	1.1641	0.7760	0.6208
150	3.1250	2.3438	1.5625	1.1719	0.7813	0.6250
151	3.1458	2.3594	1.5729	1.1797	0.7865	0.6292
152	3.1667	2.3750	1.5833	1.1875	0.7917	0.6333
153	3.1875	2.3906	1.5938	1.1953	0.7969	0.6375
154	3.2083	2.4063	1.6042	1.2031	0.8021	0.6417
155	3.2292	2.4219	1.6146	1.2109	0.8073	0.6458
156	3.2500	2.4375	1.6250	1.2188	0.8125	0.6500
157	3.2708	2.4531	1.6354	1.2266	0.8177	0.6542
158	3.2917	2.4688	1.6458	1.2344	0.8229	0.6583
159	3.3125	2.4844	1.6563	1.2422	0.8281	0.6625
160	3.3333	2.5000	1.6667	1.2500	0.8333	0.6667
161	3.3542	2.5156	1.6771	1.2578	0.8385	0.6708
162	3.3750	2.5313	1.6875	1.2656	0.8438	0.6750
163	3.3958	2.5469	1.6979	1.2734	0.8490	0.6792
164	3.4167	2.5625	1.7083	1.2813	0.8542	0.6833
165	3.4375	2.5781	1.7188	1.2891	0.8594	0.6875
166	3.4583	2.5938	1.7292	1.2969	0.8646	0.6917
167	3.4792	2.6094	1.7396	1.3047	0.8698	0.6958
168	3.5000	2.6250	1.7500	1.3125	0.8750	0.7000
169	3.5208	2.6406	1.7604	1.3203	0.8802	0.7042
170	3.5417	2.6563	1.7708	1.3281	0.8854	0.7083
171	3.5625	2.6719	1.7813	1.3359	0.8906	0.7125
172	3.5833	2.6875	1.7917	1.3438	0.8958	0.7167
173	3.6042	2.7031	1.8021	1.3516	0.9010	0.7208
174	3.6250	2.7188	1.8125	1.3594	0.9063	0.7250
175	3.6458	2.7344	1.8229	1.3672	0.9115	0.7292
196	4.0833	3.0625	2.0417	1.5313	1.0208	0.8167
197	4.1042	3.0781	2.0521	1.5391	1.0260	0.8208
198	4.1250	3.0938	2.0625	1.5469	1.0313	0.8250
199	4.1458	3.1094	2.0729	1.5547	1.0365	0.8292
200	4.1667	3.1250	2.0833	1.5625	1.0417	0.8333
201	4.1875	3.1406	2.0938	1.5703	1.0469	0.8375
202	4.2083	3.1563	2.1042	1.5781	1.0521	0.8417
203	4.2292	3.1719	2.1146	1.5859	1.0573	0.8458
204	4.2500	3.1875	2.1250	1.5938	1.0625	0.8500
205	4.2708	3.2031	2.1354	1.6016	1.0677	0.8542
206	4.2917	3.2188	2.1458	1.6094	1.0729	0.8583
207	4.3125	3.2344	2.1563	1.6172	1.0781	0.8625
208	4.3333	3.2500	2.1667	1.6250	1.0833	0.8667
209	4.3542	3.2656	2.1771	1.6328	1.0885	0.8708
210	4.3705	3.2813	2.1875	1.6406	1.0938	0.8750
211	4.3958	3.2969	2.1979	1.6484	1.0990	0.8792
212	4.4167	3.3125	2.2083	1.6563	1.1042	0.8833
213	4.4375	3.3281	2.2188	1.6641	1.1094	0.8875
214	4.4583	3.3438	2.2292	1.6719	1.1146	0.8917
215	4.4792	3.3594	2.2396	1.6797	1.1198	0.8958
216	4.5000	3.3750	2.2500	1.6875	1.1250	0.9000
217	4.5208	3.3906	2.2604	1.6953	1.1302	0.9042
218	4.5417	3.4063	2.2708	1.7031	1.1354	0.9083
219	4.5625	3.4219	2.2813	1.7109	1.1406	0.9125
220	4.5833	3.4375	2.2917	1.7188	1.1458	0.9167
221	4.6042	3.4531	2.3021	1.7266	1.1510	0.9208
222	4.6250	3.4688	2.3125	1.7344	1.1563	0.9250
223	4.6458	3.4844	2.3229	1.7422	1.1615	0.9292
224	4.6667	3.5000	2.3333	1.7500	1.1667	0.9333
225	4.6875	3.5156	2.3438	1.7578	1.1719	0.9375
226	4.7083	3.5313	2.3542	1.7656	1.1771	0.9417
227	4.7292	3.5469	2.3646	1.7734	1.1823	0.9458
228	4.7500	3.5625	2.3750	1.7813	1.1875	0.9500
229	4.7708	3.5781	2.3854	1.7891	1.1927	0.9542
230	4.7917	3.5938	2.3958	1.7969	1.1979	0.9583
231	4.8125	3.6094	2.4063	1.8047	1.2031	0.9625
232	4.8333	3.6250	2.4167	1.8125	1.2083	0.9667
233	4.8542	3.6406	2.4271	1.8203	1.2135	0.9708
234	4.8750	3.6563	2.4375	1.8281	1.2188	0.9750
235	4.8958	3.6719	2.4479	1.8359	1.2240	0.9792
236	4.9167	3.6875	2.4583	1.8438	1.2292	0.9833
237	4.9375	3.7031	2.4688	1.8516	1.2344	0.9875
238	4.9583	3.7188	2.4792	1.8594	1.2396	0.9917
239	4.9792	3.7344	2.4896	1.8672	1.2448	0.9958
240	5.0000	3.7500	2.5000	1.8750	1.2500	1.0000

Dimensions: inches.

Teeth	24 DP	32 DP	48 DP	64 DP	96 DP	120 DP
96	2.0000	1.5000	1.0000	0.7500	0.5000	0.4000
97	2.0208	1.5156	1.0104	0.7578	0.5052	0.4042
98	2.0417	1.5313	1.0208	0.7656	0.5104	0.4083
99	2.0625	1.5469	1.0313	0.7734	0.5156	0.4125
100	2.0833	1.5625	1.0417	0.7813	0.5208	0.4167
101	2.1042	1.5781	1.0521	0.7891	0.5260	0.4208
102	2.1250	1.5938	1.0625	0.7969	0.5313	0.4250
103	2.1458	1.6094	1.0729	0.8047	0.5365	0.4292
104	2.1667	1.6250	1.0833	0.8125	0.5417	0.4333
105	2.1875	1.6406	1.0938	0.8203	0.5469	0.4375
106	2.2083	1.6563	1.1042	0.8281	0.5521	0.4417
107	2.2292	1.6719	1.1146	0.8359	0.5573	0.4458
108	2.2500	1.6875	1.1250	0.8438	0.5625	0.4500
109	2.2708	1.7031	1.1354	0.8516	0.5677	0.4542
110	2.2917	1.7188	1.1458	0.8594	0.5729	0.4583
111	2.3125	1.7344	1.1563	0.8672	0.5781	0.4625
112	2.3333	1.7500	1.1667	0.8750	0.5833	0.4667
113	2.3542	1.7656	1.1771	0.8828	0.5885	0.4708
114	2.3750	1.7813	1.1875	0.8906	0.5938	0.4750
115	2.3958	1.7969	1.1979	0.8984	0.5990	0.4792
116	2.4167	1.8125	1.2083	0.9063	0.6042	0.4833
117	2.4375	1.8281	1.2188	0.9141	0.6094	0.4875
118	2.4583	1.8438	1.2292	0.9219	0.6146	0.4917
119	2.4792	1.8594	1.2396	0.9297	0.6198	0.4958
120	2.5000	1.8750	1.2500	0.9375	0.6250	0.5000
121	2.5208	1.8906	1.2604	0.9453	0.6302	0.5042
122	2.5417	1.9063	1.2708	0.9531	0.6354	0.5083
123	2.5625	1.9219	1.2813	0.9609	0.6406	0.5125
124	2.5833	1.9375	1.2917	0.9688	0.6458	0.5167
125	2.6042	1.9531	1.3021	0.9766	0.6510	0.5208
126	2.6250	1.9688	1.3125	0.9844	0.6563	0.5250
127	2.6458	1.9844	1.3229	0.9922	0.6615	0.5292
128	2.6667	2.0000	1.3333	1.0000	0.6667	0.5333
129	2.6875	2.0156	1.3438	1.0078	0.6719	0.5375
130	2.7083	2.0313	1.3542	1.0156	0.6771	0.5417
131	2.7292	2.0469	1.3646	1.0234	0.6823	0.5458
132	2.7500	2.0625	1.3750	1.0313	0.6875	0.5500
133	2.7708	2.0781	1.3854	1.0391	0.6927	0.5542
134	2.7917	2.0938	1.3958	1.0469	0.6979	0.5583
135	2.8125	2.1094	1.4063	1.0547	0.7031	0.5625
136	2.8333	2.1250	1.4167	1.0625	0.7083	0.5667
137	2.8542	2.1406	1.4271	1.0703	0.7135	0.5708
138	2.8750	2.1563	1.4375	1.0781	0.7188	0.5750
139	2.8958	2.1719	1.4479	1.0859	0.7240	0.5792
140	2.9167	2.1875	1.4583	1.0938	0.7292	0.5833
141	2.9375	2.2031	1.4688	1.1016	0.7344	0.5875
142	2.9583	2.2188	1.4792	1.1094	0.7396	0.5917
143	2.9792	2.2344	1.4896	1.1172	0.7448	0.5958
144	3.0000	2.2500	1.5000	1.1250	0.7500	0.6000
145	3.0208	2.2656	1.5104	1.1328	0.7552	0.6042
146	3.0417	2.2813	1.5208	1.1406	0.7604	0.6083
147	3.0625	2.2969	1.5313	1.1484	0.7656	0.6125
148	3.0833	2.3125	1.5417	1.1563	0.7708	0.6167
149	3.1042	2.3281	1.5521	1.1641	0.7760	0.6208
150	3.1250	2.3438	1.5625	1.1719	0.7813	0.6250

Table 3—Measuring-Pin Diameters

Diametral Pitch	Pin Diameter (in.)
24	0.0720
32	0.0540
48	0.0360
64	0.0270
96	0.0180
120	0.0144

sional limitation shown in Fig. 1. The center of pinion *B* must lie between 0.98 and 1.02 in. from the center of gear *A*. Pinions *B* and *C* are driven by gear *A* and must be in a 1:5 and a 1:3 ratio, respectively. The theoretical backlash in each mesh, based on tooth thickness, must be 0.002 to 0.004 in.

The gear ratio of 3:1 between gear *A* and pinion *C* and 5:1 between gear *A* and pinion *B* dictate that the number of teeth in gear *A* must be a multiple of 3 times 5 or 15. In order to avoid undercutting and possible interference, the smallest pinion, *B*, should have 18 or more teeth. Therefore, the possible gear and pinion combinations, in terms of number of teeth, are:

Gear *A*	Pinion *B*	Pinion *C*	*A* and *B*	*A* and *C*
90	18	30	108	120
105	21	35	126	140
120	24	40	144	160

In order to meet the dimensional restriction between gears *A* and *B*, a compromise must be made between number of teeth and diametral pitch. Table 2 indicates that the nominal center distances between gear *A* and pinion *B* for the possible meshes and preferred diametral pitches are:

Total Teeth Gear Mesh *A* and *B*	Center Distance (in.) 32 DP	48 DP	64 DP	96 DP
108	1.6875	1.1250	0.8438	0.5625
126	1.9688	1.3125	0.9844	0.6563
144	2.2500	1.5000	1.1250	0.7500

The only choice which meets all the requirements is therefore 64 diametral pitch and 126 total teeth in mesh *A* and *B*. This establishes the number of teeth for each gear as: 105 teeth for gear *A*, 21 teeth for pinion *B*, and 35 teeth for pinion *C*.

The basic dimensions of the three gears can now be taken from Table 1.

Gear	PD (in.)	OD (in.)	Nominal *M* (in.)	K_M
A	1.6406	1.6719	1.6787	2.62
B	0.3281	0.3594	0.3646	2.28
C	0.5469	0.5781	0.5841	2.42

The design requirement for backlash in each gear mesh is 0.002 to 0.004 in. It can be split equally between the pinion and gear in each mesh. The circular tooth thickness of each of the three gears must therefore be reduced 0.001 to 0.002 in The corrected measurement over pins is found by subtracting the product of K_M and the desired reduction in circular tooth thickness from the nominal measurement over pins.

For Gear *A* the maximum measurement over pins equals $M - (K_M)\ (0.001) = 1.6787 - 0.0026 = 1.6761$ in. The minimum equals $M - (K_M)\ (0.002) = 1.6787 - 0.0052 = 1.6735$ in. The measurements over pins for all three gears are:

Gear	Max. (in.)	Min. (in.)
A	1.6761	1.6735
B	0.3623	0.3600
C	0.5817	0.5793

Thus the necessary gear features are dimensioned to meet the original design requirements.

Design principles of

Feedback Control

as applied to industrial drives

By C. G. Helmick
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IN ANY feedback regulator system, output quantity to be regulated is compared to an input reference which is proportional to desired output, and the difference is kept as small as possible—ideally zero. This is accomplished by measuring both input and output, comparing them, and using the difference to control output. System components can be electrical, hydraulic, mechanical, pneumatic, or any combination of these. In addition, modern process control makes use of any number of transducers, devices that convert some process variable to a control signal for regulating purposes.

Industrial Drives: Industrial drives utilize the same principles as other regulating systems, Fig. 1, but have some special requirements of their own. Power level usually sets the industrial drive clearly apart from its counterpart, the instrument drive. A positioning servo for an analog computer, or a self-balancing potentiometer for recording instruments uses low-power components of special design to get characteristics tailored to the application. However, power ratings of most industrial drives are so large that design of these machines for ideal control characteristics is impractical.

Special features of small drive components can seldom be duplicated at industrial power levels. As a compromise, near-standard machines are used where possible, and the feedback controller recovers attendant loss in performance. Fortunately, this usually can be accomplished, but not without a thorough examination of the entire system. For high-performance systems, standard elements may have to be modified to reduce time delays, improve machine gains, or reduce saturation effects. From a cost standpoint this is nearly always less expensive than designing a new machine with special characteristics. The ultimate consideration is drive performance, and if this can be met with conventional equipment, it is the practical solution. Examples of industrial regulating systems are shown in Fig. 2.

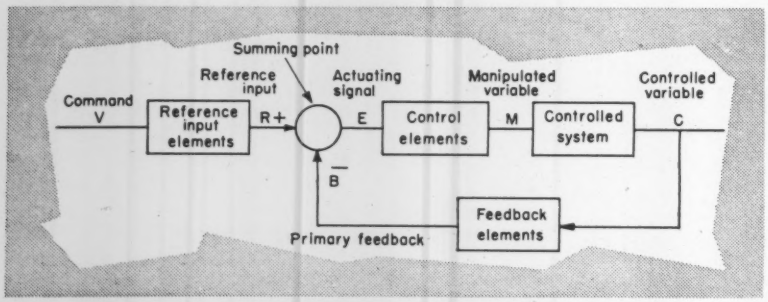

Fig. 1—Block diagram of feedback control system. Components are basic to all drive systems, but industrial power levels require modification of standard elements.

Performance: From the operat-

ing viewpoint, performance is the most important single factor. In general, quality of performance of a regulated system can be described by three factors; steady-state accuracy, system speed of response, and system damping or rate of decay of oscillations. The first term describes how closely the controlled variable normally can be held in relation to command input. Speed-of-response describes how fast normal conditions can be restored to a system after disturbance, and system damping describes the manner or quality with which normal conditions can be restored to a system after disturbance. Actually, all three performance factors are interrelated.

Steady-State Accuracy: Normal accuracy with which system output follows the command input signal depends upon system amplification. This is open-loop amplification or gain, which can be found in a simple system by taking the product of the gains of all components in the loop, including the feedback loop. The term "open loop" derives from the fact that if the control loop is opened at any point, system amplification can be found by inserting a test signal at one point of the break and measuring the signal that results at the other side of the break. The ratio of these two signals is system (or open-loop) amplification.

Adjustment for system amplification is readily made by adjusting amplifier gain. In practical industrial systems, gains of exciters, generators, or tachometers are relatively inflexible once designed. Consequently, the amplifier is provided with excessive gain, so that a simple adjustment of an input-sensitivity potentiometer produces desired system gain.

While open-loop gain is the quantity most easily adjusted, certain feedback methods can increase or decrease effect on performance. While the loop remains open, amplification is normally high. As soon as the loop is closed, however, the "through-gain" or "closed-loop" gain approaches unity. Ratio of output to input, both expressed in per-unit quantities, will be close to unity since normally the purpose of the regulator is to provide a one-to-one relationship. A large value of open-loop gain causes the ratio to approach unity. Steady-state error is based upon this idea, by measuring how much error exists between this ratio and unity. Hence, Error = $1/(1+$ open loop gain).

A steady-state error always exists unless amplification can be made infinitely large. This error is the necessary actuating signal to run the system from no-load to full-load output. Some systems, however, utilize positive feedback, or self-energization, to achieve the same effect as infinite steady-state gain. These systems actually operate with negligible steady-state error. While the steady-state gain is made very large by self-energization, this has little or no effect on gain during transients.

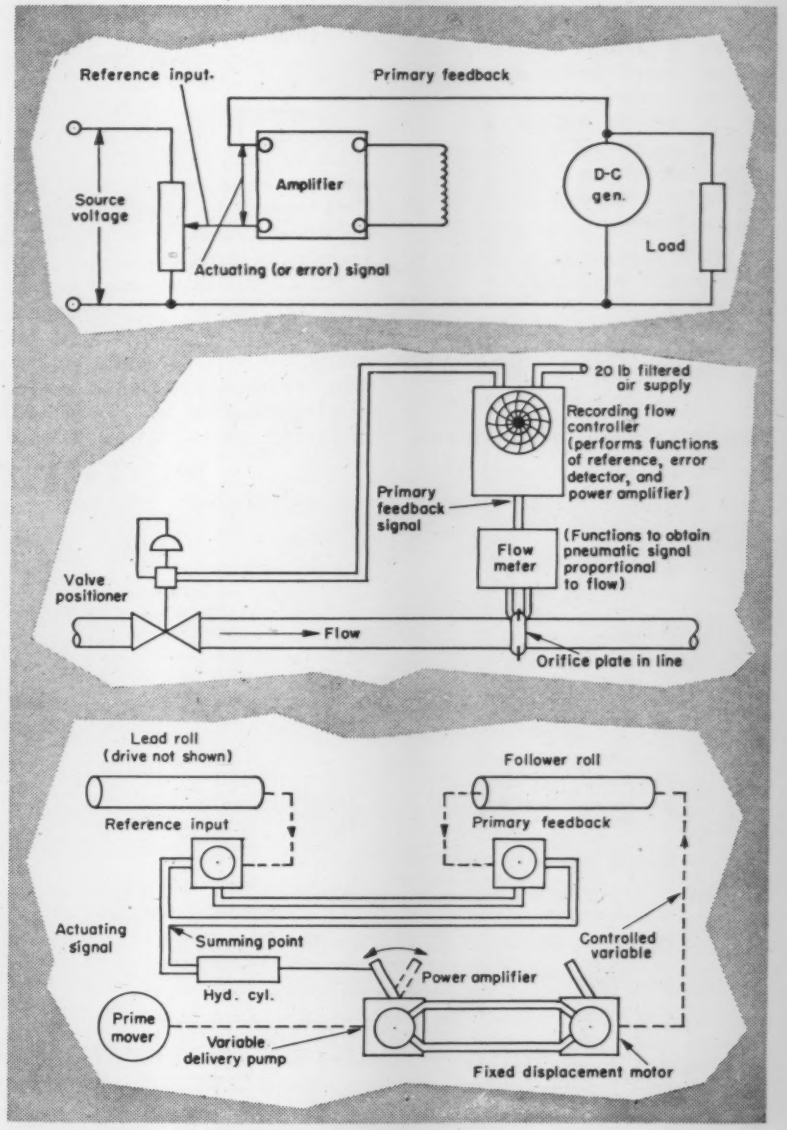

Fig. 2—Examples of industrial regulating systems using feedback control. Top to bottom, an electric regulated system for holding constant generator voltage, a pneumatic regulated system for holding constant flow rate in a pipe line, and a hydraulic regulated system for speed matching of two rolls.

Speed of Response: A system is subjected to various disturbances from time to time, and must return to normal operation rapidly and effectively. Disturbances can be caused by load changes, power-supply variations, changing machine characteristics, ambient conditons, or many other factors.

The most widely used method of measuring response to disturbances is to apply a step change to the system and observe output variation. Such a test is relatively easy to perform and represents a much more severe disturbance than the drive is likely to encounter in service. Good response under these worst conditions assures adequate field performance.

Significant aspects of transient response include:

1. Time required to first reach a specific percentage of final value.
2. Time required to reach first peak overshoot.
3. Time required for the transient to decay to a specific value.

Speed of response of any system depends on system amplification, time delays of elements comprising the system, and nature of the disturbance to which the system responds. These factors are interrelated closely. For example, system output will follow input more closely for a slow moving change than for a sudden change. Also, a system with a large delay will have a slower response than one with a small delay. The control designer relates these factors by a block diagram, Fig. 3.

High speed of response generally requires high amplification. A maximum permissible value of gain exists, however, above which the system will be unstable. A practical method of installation adjustment is to increase gain as much as possible and still avoid a hunting or oscillating condition. This value of gain is then reduced by a small amount to provide a margin for stable operation.

The oscillating condition results from interaction of component time delays when system gain becomes too high for stable operation. In all but the simplest cases, this interrelation is not obvious, and few generalizations can be made. In a simple single-delay system, response time is proportional to the single time delay involved. Any faster response time is achieved by reducing the effect of the single time delay. This can be done by increasing system gain, reducing time delay directly, or by forcing. Feedback modification of effective time delay and gain is shown in Fig. 4. For example, if the delay is an electrical field delay expressed by $T = L/R$, it can be reduced directly by increasing resistance, R. However, applied voltage must be increased to overcome added resistance drop. A practical solution often used is to reconnect a 230-v field into two parallel 115-v fields, with sufficient external resistance to operate from the 230-v supply.

Damping: Response time has little significance unless system damping is also considered. Damping from the performance standpoint describes quality of response. System damping is often measured in terms of "percent decay per cycle." This figure evaluates effect of damping regardless of response time. It is not sufficient

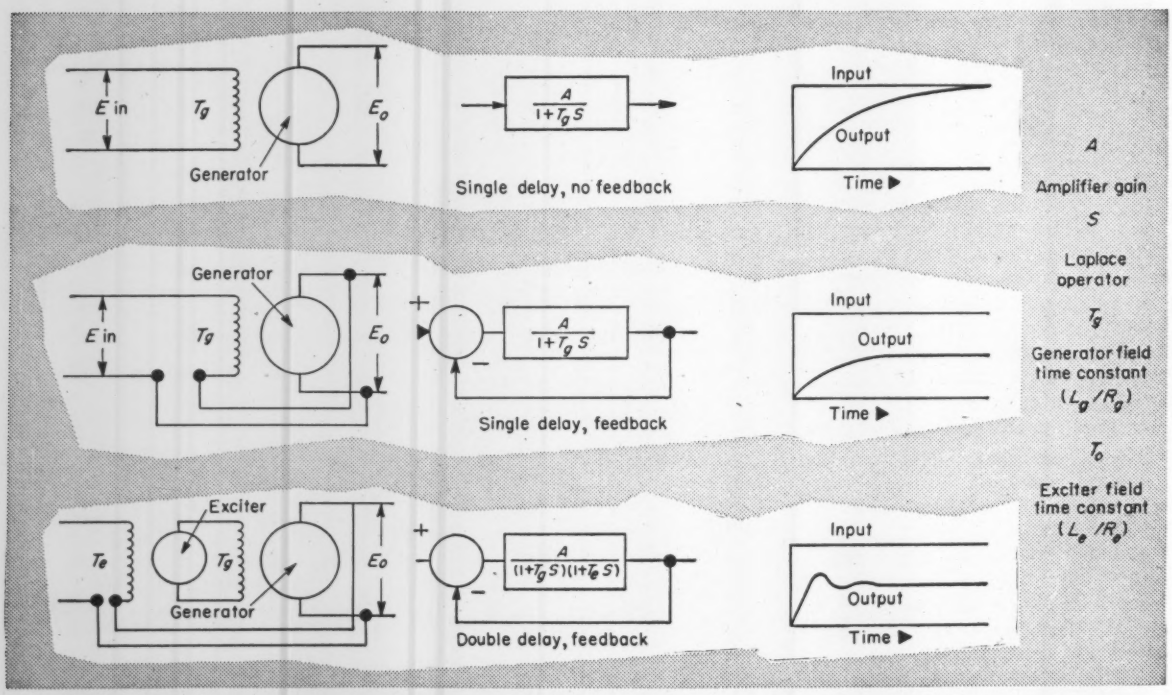

Fig. 3—Effect of time delays for a step input to three fundamental control systems. Top to bottom, a single-delay system with no feedback, a single-delay system with negative feedback to the generator field, and a two-delay system with negative feedback to the exciter field.

New nylon gun body is made in one piece, integrating three former parts in one. It weighs only 5 ounces—is easy to handle, easy to clean. Flashing, buffing and plating are eliminated because the smooth, black finish is *in* the nylon.

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The behind-the-scenes story is the new application of nylon (Du Pont's Zytel) developed after nearly two years of cooperative research by engineers of Chicago Molded, Electric Sprayit and Sears. By injection molding the entire gun mechanism in a single cavity, several machining, polishing, buffing and plating operations normally required for metal guns have been eliminated. At the same time, the finished product is two-thirds lighter—an important fatigue factor in spraying. And the nylon-to-metal screw threadings make tight seals, guard against leakage of compressed air. Furthermore, nylon is not affected by common solvents, greases, alkalis or oils, and dried paint does not tend to stick to its smooth, lustrous surface.

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to speak of decay time alone, because such a term could be the same for a fast or slow system. Effective damping may be much different.

Rate Damping or Antihunt: If the error signal is modified by a second signal proportional to output rate of change, overshooting can be reduced or virtually eliminated. The rate signal is subtracted from the normal error signal, with the net difference used to effect corrective action. In an ideal system, both normal error signal and rate signal disappear as the desired value is attained, and no overshoot occurs. In a practical system such performance can be closely attained.

This type of damping is termed rate damping, since it depends on modifying the normal error signal with a signal proportional to the rate of change of the output signal. The terms damping, antihunt, and feedback are often applied to the same fundamental concept of opposing the main actuating signal with another to caution that the system is moving too fast.

Forcing: The object of field forcing is to obtain very fast transient response by minimizing effects of normal time delays. This is accomplished by calling for a transient output that is higher than needed for the ultimate steady-state condition. If, for example, normal field voltage is applied to a dc generator, the generator field current and output voltage rise on a simple exponential curve determined by the field time constant. Consequently, field current reaches its rated value much sooner because of this field forcing. Some means is required to catch generator voltage before it becomes too high. This is the purpose of the differential field across the generator terminals, which opposes the main field as generator voltage increases. The result is a rise of field current intermediate to the two curves, but with a distinct improvement in response time. The antihunt in this case is a direct feedback opposing the main actuating signal, rather than a rate feedback. The fundamental effect is similar in that the antihunt signal acts to prevent dangerous or undesirable conditions from arising.

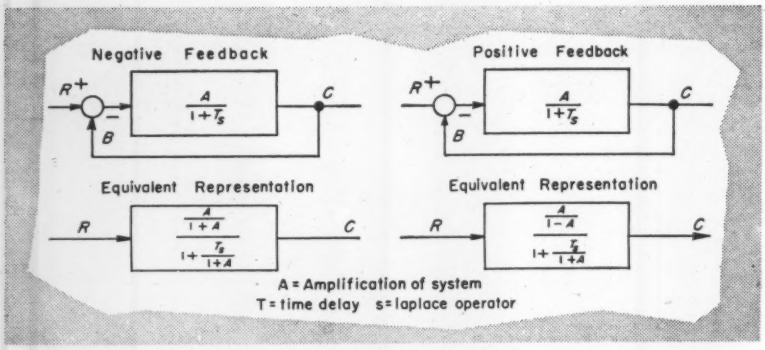

Fig. 4—Primary feedback signal opposing the reference signal in a closed-loop system, left, is negative. Open-loop amplification A is reduced to $(A/1 + A)$. Main time delay is reduced by factor $1/(A + 1)$. Positive feedback, right, has an opposite effect. Gain and time delay are increased.

From "Feedback Control Principles For Industrial Drives" in Westinghouse Engineer, March, 1957. *Vol* 7, *No.* 2.

Oral Communications—

a vital engineering tool

By Ralph Grutsch and Herbert Pritzlaff

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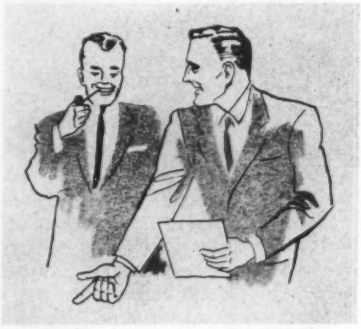

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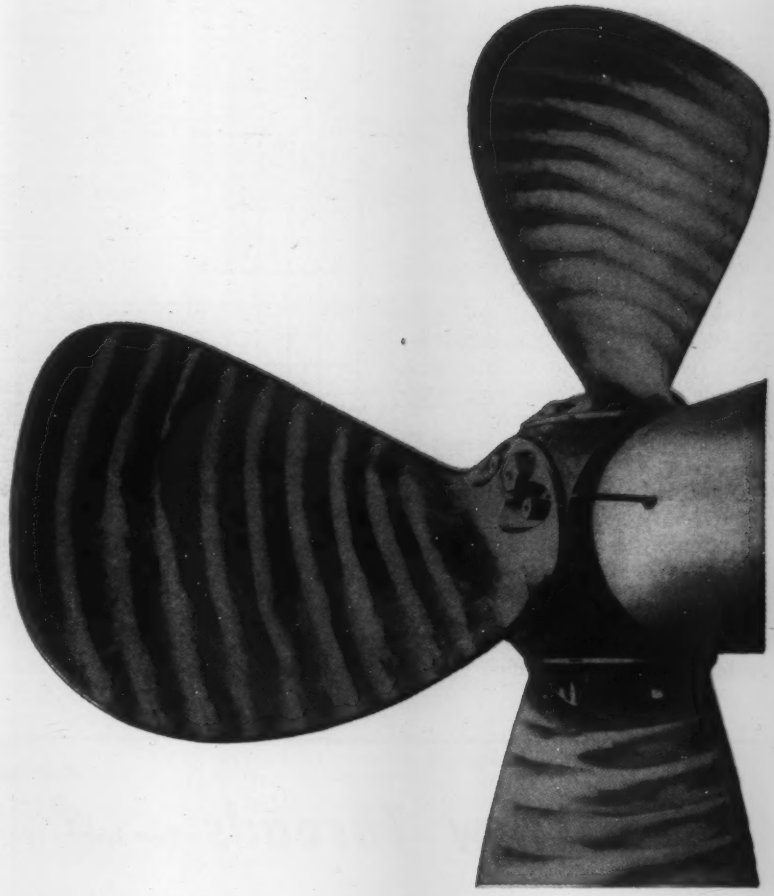

Ingeniously constructed of four blades and hub, cast separately and bolted together, this stainless steel propeller defies corrosion and erosion . . . maintains "original design" efficiency.

The terms "Electromet" and "Union Carbide" are registered trade-marks of Union Carbide Corporation.

Circle 456 on page 19

ness in oral communciations is basic to the entire program. Brief sessions of a small group are held in which individual presentations are confined to single subject facets for approximately ten minutes. Each person evaluates his own talents, abilities and mannerisms so that his presentation of ideas will be more effective because they reflect his personality.

Assignments for presentation at these sessions are made in advance, and sources of information are suggested to participants. Therefore, in the normal course of his daily activity, each participant makes his own arrangements for fact-finding interviews. The interviews themselves afford practice in oral communication.

Since it is often required that men think in terms of unexpected problems during discussion, development of presentation techniques natural to each individual is important. Blueprints, mathematical symbols, models, and samples are accepted modes of idea conveyance. Development of these and other visual aids is encouraged.

Visual aids must be selected on the basis of what is available, what subject matter will be discussed, and group size. For example, blueprints are appropriate for a group of three or four people but are not effective with a dozen or more people. To be most effective, these visual aids must become almost an extension of the individual making the presentation. Discussion of a particular design logically leads to drawings, pictures, models or devices that show features and advantages of the design. From various devices available, each person is encouraged to select those easiest for him to use effectively. A general guide to visual aid selection is given in Table 1.

From "Oral Communication—An Important Part of Engineer's Daily Life" in Allis-Chalmers Electrical Review, *Vol. 22, No. 1.*

Table 1—Guide To Visual Aid Selection

Group Size					Visual Aid	Information										
2-5	5-10	10-15	15-20	Over 20		Curves & Graphs	Diagrams & Charts	Sketches & Outlines	Equation Development	Theory Development	How to	Physical Features	Listings & Tables	Pictures	Appearance	Internal Construction
X					Blueprints							X			X	X
X	X				Flip Charts	X	X	X	X	X	X	X	X	X	X	X
X					Slide Viewers						X	X		X	X	
X					Photographic Prints	X	X				X			X	X	
X	X				Bulletins	X	X	X	X	X	X	X	X	X	X	X
X					Samples							X			X	
					Scale Models							X			X	
X	X	X			Cutaway Models							X			X	X
	X	X	X		Posters & Cards	X	X	X	X	X	X	X	X	X	X	X
	X	X	X	X	Blackboard			X	X	X			X			X
		X	X	X	Flannel Board	X	X		X	X			X			
					Projectors											
		X	X	X	Slide (Silent)	X	X				X	X		X	X	
			X	X	Slide (Sound)	X	X			X	X	X		X	X	
	X	X	X	X	Overhead	X	X	X	X	X		X				
	X	X	X	X	Opaque	X	X					X		X	X	
			X	X	Movie	X	X	X	X	X	X	X	X	X	X	X

Screw Threads for high-temperature bolting

By P. G. Schulz
Assistant Engineer of Standards
Crane Co.
Chicago

PROBLEMS attendant to bolting in high-temperature services have received attention since working temperatures in installations have been increasing. Carbon steel bolts had proved satisfactory in the lower range of temperatures, but bolt troubles encountered with higher temperatures made it apparent that materials of greater elastic strength and creep resistance were necessary, and that special consideration must be given the threading involved in elevated-temperature applications.

Present specifications of the American Society for Testing Materials covering alloy bolting steels reflect the work of its early subcommittee on high-temperature materials. It was established early in

· *Another cost-saving application of* **Amplex Powder Metallurgy**

With a modern power saw—easy does it. It's easier on the inside, too, because this manufacturer has equipped vital components with extra tough, greater wear resistant OILITE precision parts. The manufacturer's report indicates that OILITE powder metal sprockets and gears offer *greater wear resistance than alloy steels.*

Furthermore, in using OILITE precision parts the manufacturer of the power saw realizes *substantial cost savings over parts fabricated by any other process.*

What this manufacturer is accomplishing with OILITE precision parts, you can too. Or, perhaps, in your case OILITE self-lubricating bearings and bearing materials can help you lick the problem of providing lubrication in hard-to-get-at places. In permanent metal filters, too, OILITE provides a wide choice of shapes, sizes and porosities to meet product requirements.

Amplex—volume producer of Chrysler-engineered powder metal components—can meet your production schedules with on-time deliveries in any quantity.

Helping solve the problem of others is a daily occurrence at Amplex. This Chrysler-Amplex engineering service is available to you too.

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BEARINGS • FINISHED MACHINED PARTS • PERMANENT METAL FILTERS • FRICTION UNITS • FERROUS AND NON-FERROUS METALS

Circle 457 on page 19

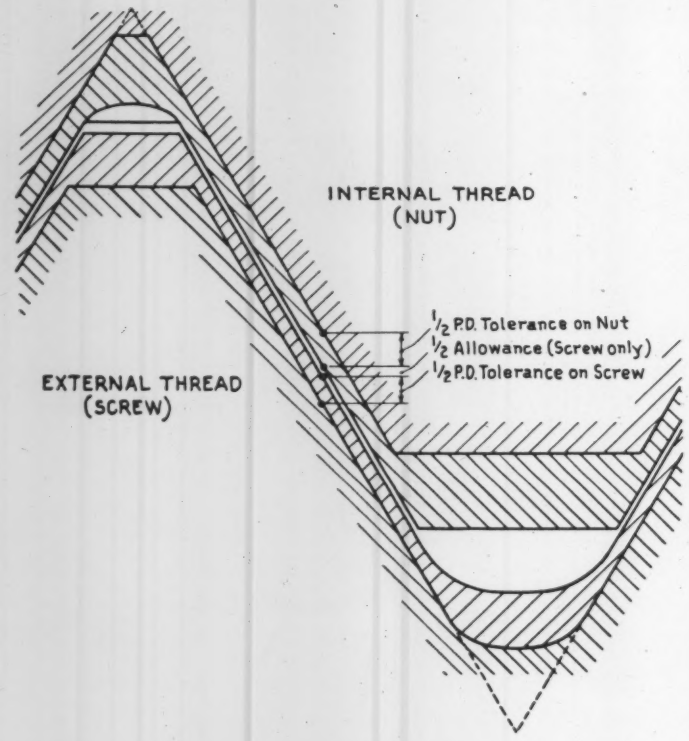


Fig. 1—Bolting assembly, showing allowance or neutral zone, desirable for high-temperature work. The neutral zone is an intentional minimum clearance between pitch diameters of screw and nut. Possibility of seizure is minimized by this space provision for lubricant which can reduce torque by 50 per cent.

Table 1—Straight Screw Threads for High-Temperature Bolting*

Diameter	Allowance (Minimum Clearance) Class 7	Allowance (Minimum Clearance) Class 2A	Tolerance External Class 7	Tolerance External Class 2A	Tolerance Internal Class 7	Tolerance Internal Class 2B	Average Clearance Combination of Class 2A and Class 2B Class 7	Average Clearance Combination of Class 2A and Class 2B Class 2B
¼	0.0010	0.0011	0.0026	0.0037	0.0036	0.0048	0.0041	0.0054
5/16	.0011	.0012	.0030	.0040	.0041	.0053	.0047	.0059
⅜	.0013	.0013	.0032	.0044	.0045	.0057	.0052	.0064
7/16	.0013	.0014	.0036	.0047	.0049	.0061	.0056	.0068
½	.0015	.0015	.0037	.0050	.0052	.0065	.0060	.0073
9/16	.0016	.0016	.0040	.0052	.0056	.0068	.0064	.0076
⅝	.0017	.0016	.0042	.0055	.0059	.0072	.0068	.0080
¾	.0019	.0018	.0045	.0059	.0064	.0077	.0074	.0086
⅞	.0021	.0019	.0049	.0063	.0070	.0082	.0081	.0092
1	.0022	.0020	.0054	.0068	.0076	.0088	.0087	.0098
1⅛	.0024	.0021	.0055	.0069	.0079	.0090	.0091	.0101
1¼	.0025	.0021	.0058	.0070	.0083	.0092	.0096	.0102
1⅜	.0025	.0022	.0061	.0072	.0086	.0093	.0099	.0105
1½	.0027	.0022	.0063	.0073	.0090	.0095	.0104	.0106
1⅝	.0028	.0022	.0065	.0074	.0093	.0097	.0107	.0108
1¾	.0029	.0023	.0068	.0075	.0097	.0098	.0112	.0110
1⅞	.0030	.0023	.0070	.0077	.0100	.0100	.0115	.0112
2	.0031	.0023	.0073	.0078	.0104	.0101	.0120	.0113
2⅛	.0032	.0024	.0075	.0079	.0107	.0102	.0123	.0115
2¼	.0033	.0024	.0077	.0080	.0110	.0104	.0127	.0116
2⅜	.0035	.0024	.0082	.0082	.0117	.0106	.0135	.0118
2¾	.0037	.0025	.0087	.0083	.0124	.0108	.0143	.0121
3	.0038	.0026	.0092	.0085	.0130	.0111	.0149	.0124
3¼	.0039	.0026	.0093	.0087	.0132	.0113	.0152	.0126
3½	.0040	.0026	.0093	.0088	.0133	.0115	.0153	.0128

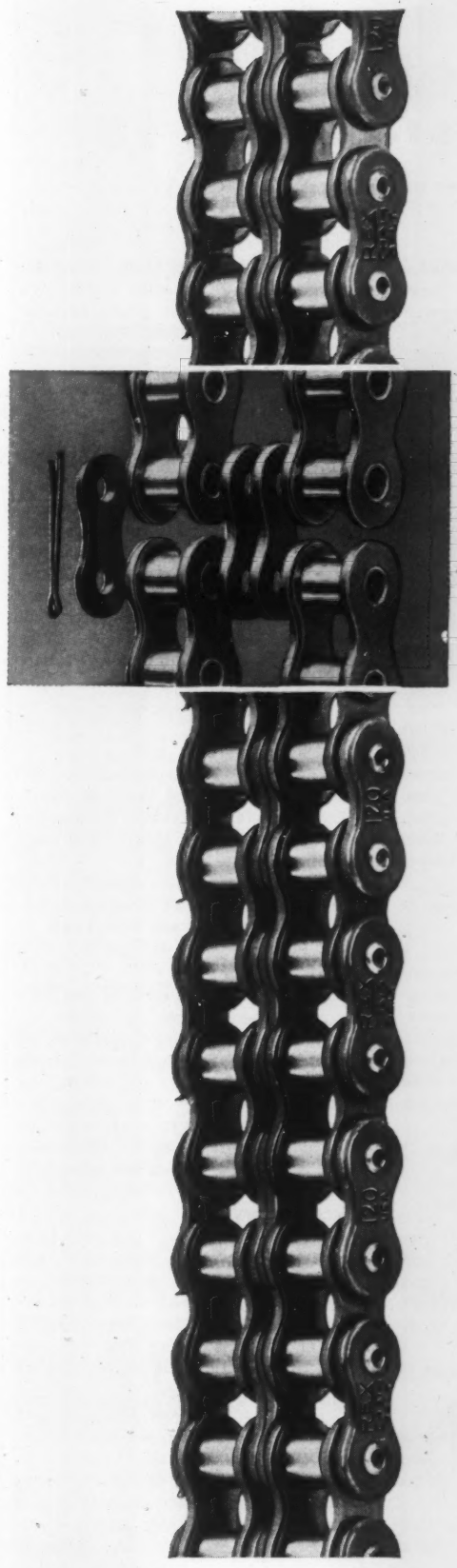
*Dimensions shown (in.) apply to pitch diameters.

these investigations that American Standard Coarse Thread Series threads are satisfactory for diameters 1 in. and smaller, but not so for diameters over 1 in. Tests were conducted on finer pitches as well as on other thread forms with the subsequent, almost universal, adoption of the 8-thread series of U.S. form for diameters over 1 in. The use of 8 threads per inch provided 5.0 per cent more area at the root of the thread on the 1⅛ in. diam, 8.5 per cent more area on the 1½ in. diam, and 15.2 per cent more area on the 2 in. diam.

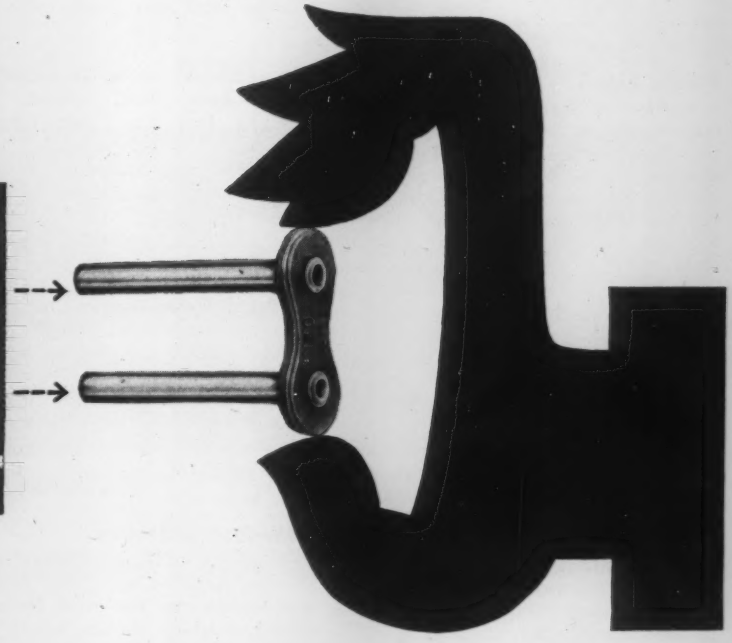
An allowance or neutral zone is desirable when using bolting for high temperature work. The allowance, which is an intentional minimum clearance between the pitch diameters of screw and nut, is illustrated in Fig. 1. With this space provision for lubricant, the possibility of seizure is minimized when these assemblies are subjected to the high temperatures for which they are recommended. Experience and tests have shown that a suitable lubricant is very essential on bolt threads subjected to high temperatures to prevent galling or seizing when removing the nuts. Also, the proper lubricant causes as much as a 50 per cent reduction in torque applied to produce a given stress in bolts, as compared with nonlubricated assemblies and proportional decreases in assemblies with inferior lubricants.

Table 1 gives a comparison of the cancelled Class 7 thread with the Class 2A-2B combination. Note that the differences are slight and the last two columns show conditions which are practically alike throughout the entire range of sizes. Class 2A and 2B allowances and tolerances have been determined on the basis of experience beyond that available when Class 7 was originated and modified slightly to comply with empirical formulas. Threads made to American Standard B1.4 are interchangeable with those made to American Standard B1.1, Class 2A and 2B and vice versa. In the interim period, pending complete changeover to Class 2A and 2B, either thread should prove satisfactory.

From "Screw Threads for High-Temperature Bolting" in Fasteners, *Vol. 12, No. 1, published by Industrial Fasteners Institute, Cleveland.*



REX® GLIDE FIT



A new concept in Roller Chain Design

CONVENIENCE. New ease of coupling and uncoupling for multiple-width chains. Pins are a "glide fit" through inner link plates...a press fit only in the outer link plates.

LONG LIFE. You get the great convenience of Rex Glide Fit Roller Chains *plus* long life. Properly applied, there's no sacrifice of life or strength to gain the easy coupling.

ECONOMY. The long life and easy coupling of Glide Fit Roller Chains mean lower operating costs...less nonproductive down time. You can couple these chains *faster*... uncouple them *faster!*

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CHAIN BELT

Leadership...through creative engineering

Circle 458 on page 19

Helpful Literature
for Design Executives

For copies of any literature listed, circle Item Number on Yellow Card—page 19

Plastic Pipe

Application, installation and specifications of SP plastic pipe, made from a polyethylene resin, are covered in catalog 401. Working pressures, heat resistance and chemical resistance are detailed. Orangeburg Mfg. Co.

Circle 621 on page 19

Plastic Components

Precision machined electronic, chemical and mechanical plastic components, subject of bulletin GBA 2587, are made from Teflon, Kel-F, nylon, phenolics, silicone, Rexolite, styrenes and Formica. Important material properties are given. 4 pages. Tri-Point Plastics, Inc.

Circle 622 on page 19

Staked Fastener

Type M My-T-Grip staked fastener that provide load-bearing threads in thin free-flowing material is described in catalog M 200. Installation drawings and torque values obtainable are included, along with selection tables. 4 pages. My-T-Grip Mfg. Co.

Circle 623 on page 19

Pipe Line Venturi Tube

When installed in standard pipe lines, the venturi tube is used for metering water, sewage, sludge, air, and other fluids. The differential pressure producer is described and illustrated in bulletin 400. Application data are presented. Burgess-Manning Co., Penn Instruments Div.

Circle 624 on page 19

Relief Valves

Line of chemical relief valves and back pressure valves in ¼, ½, ¾ and 1-in. sizes for pressures to 1500 and 200 psi, respectively, is described in illustrated bulletin 357. Dimensions and materials of construction are covered. 4 pages. Milton Roy Co.

Circle 625 on page 19

Alloy Machine Parts

"Long Wearing Machinery Parts Made of Haynes Alloys" is title of design manual. Complete data are given on physical and mechanical properties of various alloys including cobalt base cast, cobalt base wrought, iron base cast, tungsten carbide and nickel base cast types. Heat treatment, machining, grinding, joining and forming guidance is offered. 48 pages. Haynes Stellite Co.

Circle 626 on page 19

Control Valves

Aircraft hydraulic pressure systems requiring smooth and steady directional control can make use of series 1701 hydraulic control valves, described in illustrated data sheet 824. Basic design provides two-way control, with ½-in. slide travel. 2 pages. Lyndon Aircraft Corp.

Circle 627 on page 19

Adhesives & Sealers

Industrial materials selection chart includes data on adhesives, coatings and sealers for use with reclaimed rubber, synthetic rubber, latices, plastic, epoxy resins and caulkings. Characteristics, color, solvent and other data are included. Miracle Adhesives Corp.

Circle 628 on page 19

Semiautomatic Welding

"A Better Way to Weld Steel," "New Continuous-Feed Arc Welding" and "'Unionarc' Welding Process" are three bulletins on this semiautomatic welding process which uses continuously-fed bare wire, powdered magnetic flux and carbon dioxide gas. 8, 4 and 8 pages. Linde Co.

Circle 629 on page 19

Nickel Alloy Wire

"How to Design with Nickel Alloy Wire" booklet covers such wire as Monel, nickel, Inconel, Inconel X and stainless and heat resisting steels. Answers to actual problems are given, and a material selection guide is included. 6 pages. Techalloy Co.

Circle 630 on page 19

Magnetic Engineering

Three vital functions performed by the G-E magnetic engineering laboratory are described in illustrated brochure. They are evaluation of magnetic circuit design, establishment of test methods and standards, and investigations of basic magnetic phenomena. Publication points out how a user can get more for his money with permanent magnets. 12 pages. General Electric Co., Metallurgical Products Dept.

Circle 631 on page 19

Leather Packings

Revised handbook on the design and application of mechanical leather packings contains the latest information from National Industrial Leather Association. Data on leather, various types of packings, washers, gaskets, diaphragms, cylinder surface finish, and hydraulic fluids are included. Glossary of terms and many tables are also included. 56 pages. Albert Trostel Packings, Ltd.

Circle 632 on page 19

Extruded Plastics

Dimensional tables in bulletin 105 cover tubing and rod made of nylon, cellulose-acetate-butyrate, methacrylate, polyethylene, polystyrene and vinyl. Coils, reels and straight lengths are available. Specifications are presented. Jessall Plastics, Inc.

Circle 633 on page 19

Noise Control

Charts and photographs in brochure "Noise Control" illustrate applications of pneumatic mufflers for elimination of exhaust noise of air operated equipment. Performance data on frequency and attenuation levels and other information are included. 8 pages. Allied Witan Co.

Circle 634 on page 19

Accelerators

Four models of G-accelerators or centrifuges used to subject aircraft and missile components to simulated operational G-loadings are described in illustrated catalog. G-range varies from 0.02 to 1000 G. Specifications of all models are given. Genisco, Inc.

Circle 635 on page 19

Casters & Wheels

Illustrations and specifications of hundreds of types and sizes of casters and wheels for many requirements are found in catalog 125. Included

HOWELL MOTOR BRIEFS

Quick facts for those who design-in and specify electric motors

Gearmotors — speed . . . *and cost* . . . reducers!

Where driven speeds less than normal motor speeds are required, there are good reasons for using a gearmotor as opposed to a motor-plus-reducer-plus-coupling arrangement. Here are some of them:

1. **LOWER FIRST COST** is a big advantage—see table in adjoining columns for some specific comparisons.
2. **COMPACTNESS** that can give you significant space savings — plus a *better looking* drive.
3. **STANDARDIZATION** — fewer parts for you and your customers to stock. NEMA-standard gearmotors, like Howell's, are completely interchangeable — Howell ships them from stock.
4. **GREATER RELIABILITY** — With one integral unit and direct coupling, chances for wear and failure are greatly reduced.

Gear Hardness Counts

The degree of compactness and reliability you get in a gearmotor is dependent in good measure upon the hardness of the gears. Howell's parallel shaft units have gears machined to close tolerances from steel substantially harder (Rockwell 52-60) than is average in the industry. Result — a smaller gear package with superior wear resistance. Howell right angle units have precision ground steel worms integral with shaft, and worm gears made of high grade alloy bronze.

The right angle type of gearmotor is a recent addition to the Howell Motor line and complements the parallel shaft series. A Howell sales engineer will be glad to show you which is best for your application.

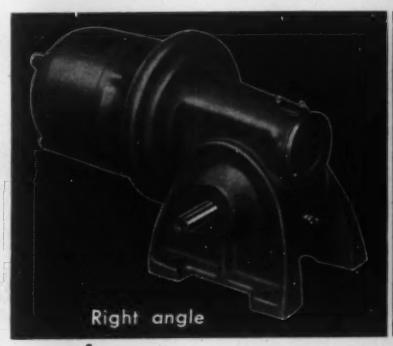
Note This Versatility

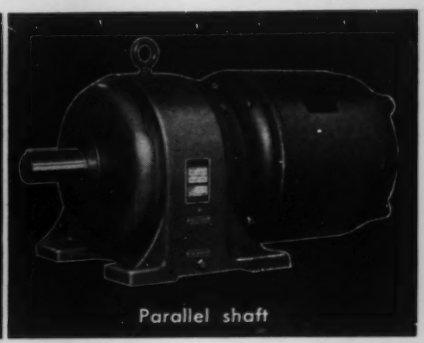
Howell is one of the few manufacturers to offer gearmotors with the motor of any electrical or mechanical type. Electrical types available include elevator and hoist, slip ring, torque and multi-speed motors.

Mechanically, they can be supplied in various types of enclosures — either with feet or with flanges for mounting horizontally or vertically. Optional accessory equipment includes brakes and zero speed switches.

see our catalog in S or write for copy

Howell Gearmotor Capacities:
Parallel Shaft: 1 to 150 hp
Right Angle Shaft: ⅛ to 40 hp


Right angle


Parallel shaft

***savings*— Howell Gearmotors vs. Separate Motor, Reducer, Coupling and Base — based on open motor and Class I gears**

I. Ratio 11.4 to 1 or 155 RPM with 1750 Motor

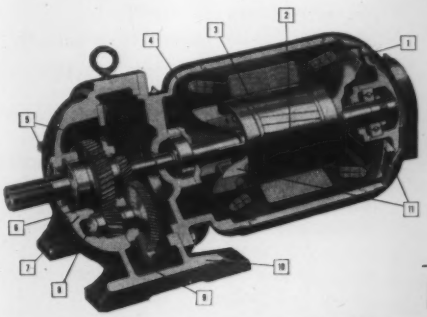
HORSEPOWER	GEARMOTOR SIZE	REDUCER SIZE	GEARMOTOR SAVINGS*
1	21A-203	21-SL	$106.76
1½	21A-204	21-SL	82.38
2	21A-224	21-SL	60.12
3	21A-225	21-SL	28.32
5	21A-254	22-SL	35.52
7½	23A-284	23-SL	101.10
10	23A-324	23-SL	52.70

II. Ratio 86.5 to 1 or 20 RPM with 1750 Motor

1	32A-203	32-SL	$ 71.30
1½	33A-204	33-SL	134.08
2	33A-224	33-SL	78.96
3	34A-225	34-SL	154.42
5	34A-254	34-SL	43.06
7½	35A-284	35-SL	236.80
10	35A-324	35-SL	111.40

*Complete cost breakdown furnished on request

11 reasons why Howell Gearmotors last longer, serve you better



1. High-quality insulation
2. Copper-clad rotor
3. Expert Craftsmanship
4. High-quality coil varnish
5. Leakproof oil seals
6. Duti-Rated Lifetime Gearing
7. Unit case construction with integral bearing housings
8. Corner-mounted offset shaft
9. Large oil reservoir
10. Heavy, cast-iron construction
11. Superior cooling

Write for Bulletin GM-1

HOWELL Red Band MOTORS

HOWELL MOTORS

HOWELL ELECTRIC MOTORS COMPANY, HOWELL, MICHIGAN

PRECISION-BUILT MOTORS FOR INDUSTRY SINCE 1915

Circle 459 on page 19

are rigid and swivel forged; plate, cast, pressed and semisteel single and double wheel model casters; and steel, semisteel, hard rubber and molded plastic wheels. Various tire materials are offered. 56 pages. Hamilton Caster & Mfg. Co.

Circle 636 on page 19

Steel Stamps

Mecco safety steel stamps, holders, fixtures and other marking devices are illustrated in bulletin SS-120. Examples of type faces are shown and ordering data are included. 4 pages. M. E. Cunningham Co.

Circle 637 on page 19

Multiheaders & Plugs

Vac-Tite compression multiheaders and plugs are briefly described in condensed catalog 657-K. Essential information on 10,000 different types is included. Hermetic Seal Corp.

Circle 638 on page 19

Solenoids

Continuous duty and intermittent (25 per cent) duty ratings of five solenoid types are listed in illustrated catalog. Suited for wide variety of applications, the solenoids are described as to their construction and dimensions. 4 pages. W. L. McMichael, Inc.

Circle 639 on page 19

Wheels & Casters

Line of semipneumatic wheels and light and medium duty casters is subject of illustrated catalog 400. Wheels have 4½ to 12-in. diameters and casters have 2½ to 6-in. diameter wheels. Load capacities are 30 to 350 lb and 75 to 650 lb, respectively. 16 pages. Gleason Corp.

Circle 640 on page 19

Auxiliary Power Systems

Auxiliary power systems for missiles or manned aircraft are detailed in illustrated brochure A-16. They provide electric, hydraulic or other power. Outlined are basic components, monofuels, monopropellant turbines, speed controls, power system volumes and other technical data. 12 pages. Walter Kidde & Co.

Circle 641 on page 19

Oscillator Controls

Frahm resonant reed oscillator control, an electromechanical device for use in electric oscillators, is subject of illustrated bulletin 34-10. It maintains any oscillator frequency within close limits between 20 and 1100 cps. Included are application data and specifications. 12 pages. James G. Biddle Co.

Circle 642 on page 19

Gearmotors

Expanded line of parallel shaft Electra-Gearmotors in both built-in and motor-coupled types is subject of illustrated catalog 60-2. Descriptions and specifications are included. 24 pages. Electra Motors Inc.

Circle 643 on page 19

Diaphragm-Operated Valves

Direct-acting, reverse-acting and three-way diaphragm operated valves, illustrated in descriptive bulletinV-8, are built for 250-psi maximum steam service. Recommended diaphragm air pressure is 25-35 psi. Dimensions and pressure data are in table form. 4 pages. Seely Instrument Co.

Circle 644 on page 19

Investment Castings

Close tolerance, smooth finish and wide selection of alloys are among advantages of Accumet precision investment castings outlined in illustrated brochure. Process is described, and composition and properties of alloys are included in tables. Typical castings are shown. 16 pages. Crucible Steel Co. of America.

Circle 645 on page 19

Resistors

Data on Gray Line axial-lead resistors with matched heat expansion to withstand high temperatures are presented in bulletin. They are available in 3, 5 and 10-w ratings with resistances from 1 to 10,000, 25,000 and 50,000 ohms, respectively. 2 pages. Hardwick, Hindle Inc.

Circle 646 on page 19

Hydraulic Tubing

Mechanical, pressure, heat exchanger, condenser, hydraulic oil line, pump cylinder, precision ground and special shape Summerill hydraulic tubing which features the new bright Hydraluster finish is subject of bulletin. Working pressure, sizes, available grades and other data are listed. 4 pages. Summerill Tubing Co.

Circle 647 on page 19

Metalworking Data

"Computations for Metal Working in Presses" is title of handbook No. 38. It contains information and alignment diagrams for computing pressure and sustained work capacity of presses, as well as pressure and work requirements of the job to be performed. Formulas and charts are included on blanking, shearing, drawing, reducing, ironing, coining, sizing, forging and extrusion. 50 pages. E. W. Bliss Co.

Circle 648 on page 19

Adjustable Power Supplies

Five standard models of adjustable voltage, metered power supplies for laboratory testing, production line and maintenance use are described in bulletin 801. They are available in 60-cycle 120 and 240-v models in eight current ranges from 0.5 to 100 amp with output up to 12 kw. 4 pages. Dayton Electric Mfg. Co.

Circle 649 on page 19

Quick-Release Pins

Practical reference information for design engineers on 5440 sizes and types of single-acting self-locking quick-release pins is presented in bulletin ADI 1268-257. Pins are particularly suited for aircraft uses. 6 pages. Aviation Developments Inc.

Circle 650 on page 19

Aluminum in Screw Machines

Guidance in the tooling, techniques and procedures to be used in machining aluminum stock in automatic screw machines is afforded by illustrated book entitled "Alcoa Aluminum in Automatic Screw Machines." 104 pages. Aluminum Co. of America.

Circle 651 on page 19

Custom Molding

Details of a new custom molding service which includes compression and transfer techniques for electronic and chemical resistant parts are presented in catalog sheet. Physical and electrical properties of epoxy compound are listed. 2 pages. Epoxy Products, Inc.

Circle 652 on page 19

Electrical Tubing

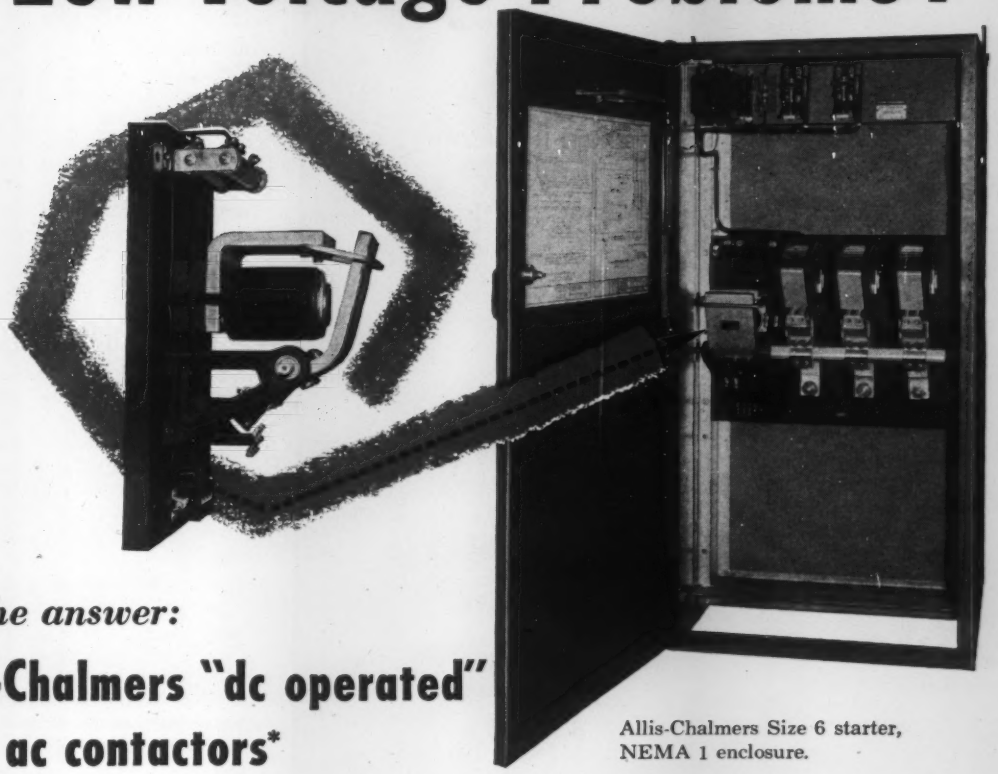
Pricing guide for available types and sizes of plastic and coated insulating tubings also includes selector chart containing application information. Properties and specifications are given on various types. 16 pages. Minnesota Mining & Mfg. Co., Irvington Div.

Circle 653 on page 19

Variable Pitch Sheaves

Maxi-V-Pich sheaves in stationary and motion control types for V-

Dirt, Corrosion, Low Voltage Problems?



the answer:

Allis-Chalmers "dc operated" ac contactors*

Allis-Chalmers Size 6 starter, NEMA 1 enclosure.

Dc operators in Allis-Chalmers control assure dependable performance because they are not affected by dirt or corrosion on the armature face. Positive magnetic operation reduces contact pitting — eliminates hum and chatter—prolongs mechanical life. The operator picks up at 65% of rated voltage — holds in with as little as 35%.

For Any Low Voltage, High Horsepower Application . . . Allis-Chalmers Modern Control — Sizes 4, 5 and 6

Advanced Electrical Design

ACBO arc-centering blowout sharply curtails arcing time, greatly prolongs contact and chute life — without blowout coils.

Simplified Mechanical Design

Streamlined clapper-type construction permits natural arc rise in arc chute. Sensible enclosure dimensions provide ample wiring space. Easy accessibility simplifies maintenance.

For detailed information on this complete line of modern control, call your A-C Control Distributor or A-C District Office. Or write Allis-Chalmers, General Products Division, Milwaukee 1, Wisconsin.

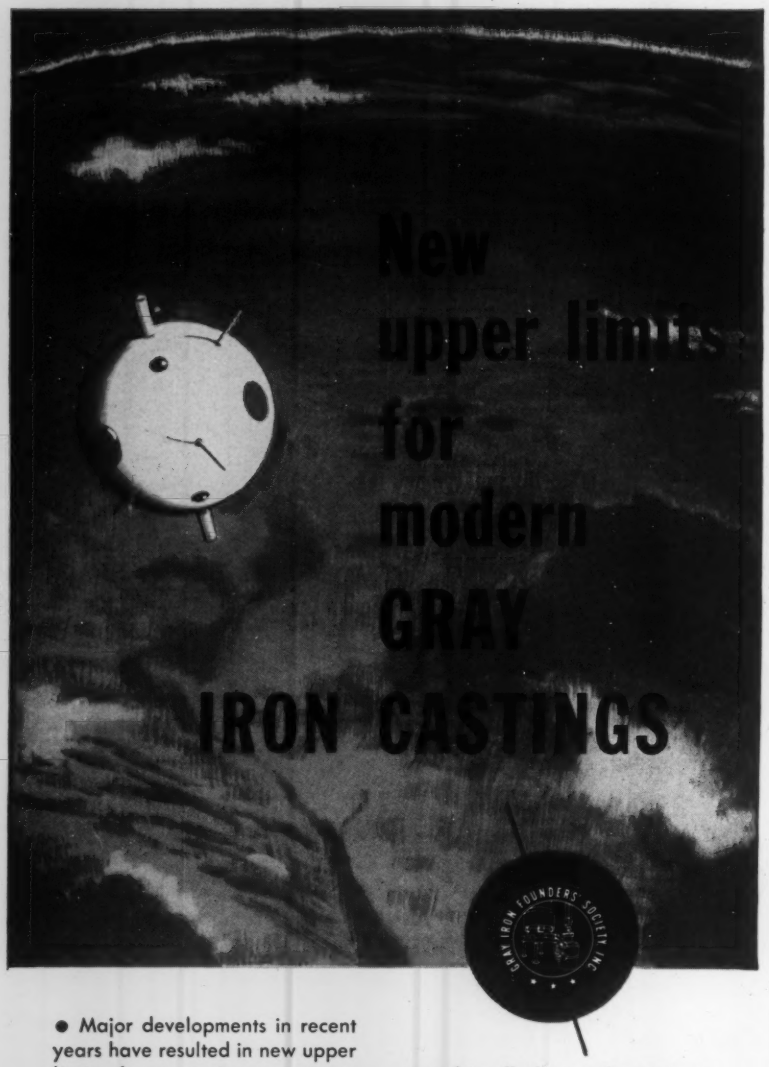
*Self-contained ac to dc circuit. Standard in Size 6, optional in sizes 4 and 5.

ALLIS-CHALMERS

A5372

ACBO is an Allis-Chalmers trademark.

Circle 460 on page 19



• Major developments in recent years have resulted in new upper limits for gray iron castings. Modern metallurgy is providing irons in a wider range of mechanical and physical properties. Improved materials and new molding techniques are producing castings with a better surface finish and closer dimensional accuracy. Instrumentation and control in all phases of gray iron production are boosting quality. As a result of these accomplishments, modern gray iron castings are replacing other production materials—even so-called miracle metals—in countless applications heretofore considered impossible to cast in gray iron.

Free Summary of Specifications. *Be sure you are fully acquainted with the new "upper limits" of gray iron. Write for a copy of GIFS up-to-date "Summary of Specifications."*

it's time to design with

GRAY IRON CASTINGS

GRAY IRON FOUNDERS' SOCIETY, INC.
National City-East 6th Bldg. • Cleveland 14, Ohio

Circle 461 on page 19

Helpful Literature

belt type variable speed drive service are subject of illustrated bulletin. Interchangeable split tapered bushings simplify installation. 8 pages. V-Belt Engineering Co.

Circle 654 on page 19

Miniature Counter

Magnetically-actuated Abrams magnetic counters, with three or four additive or subtractive wheels, can operate at speeds to 1200 counts per minute. They can be supplied with 6, 12, 24 or 110-v dc coils and draw approximately 3.5 w. Complete details are given in bulletin AIC-1014. 4 pages. Abrams Instrument Corp.

Circle 655 on page 19

Liquid Gage Illuminator

Data unit No. 300 shows design and application details on the new gage illuminator for liquid level gages. This explosionproof unit is of the solid-wedge lighting type and uses a 58-w bulb. 2 pages. Jerguson Gage & Valve Co.

Circle 656 on page 19

Electro-Mechanical Assemblies

Instruction book SBI-1 contains revised data tables of common gear ratios and moments of inertia for Servoboard electro-mechanical assembly kits. It explains how to install components in hangers, mounting hangers and gears, align gears and select gears. 8 pages. Servo Corp. of America.

Circle 657 on page 19

Entrainment Separator

Details of the new Karbate brand impervious graphite entrainment separator are given in catalog section S-6900. This corrosion resistant equipment removes entrained liquids from gas streams at rates up to 2300 lb per hr. 4 pages. National Carbon Co.

Circle 658 on page 19

Potentiometers

Specifications, diagrams and general information are given in data HP-500 on the new 5-in. high-resolution precision potentiometer. 2 pages. De Jur-Amsco Corp.

Circle 659 on page 19

Vibration Meter

Vibrational velocity, displacement and frequency determinations are quickly made with the type 1-117 vibration meter described in illustrated bulletin 1538C. This portable tool

Elongation test of sample heelpiece metal typifies quality control measures that leave nothing to chance at Automatic Electric.

STANDARDS THAT DETERMINE RELAY QUALITY/

a distortion-proof heelpiece

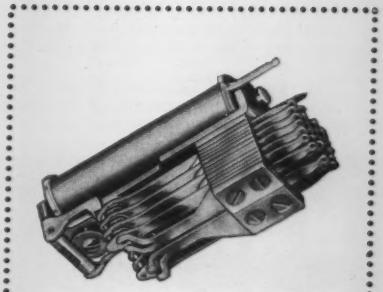
53 dimensional checks assure perfect alignment

The heelpiece of a relay is the platform on which all other parts rest. To maintain accurate contact spacing and pressure, the heelpiece must never shift, never twist, never bend.

We insure flatness and dimensional stability on both Class A and Class B relays, by planishing the heelpiece to relieve strains. In addition, we exercise unusual accuracy in the positioning, drilling and tapping of the holes, in forming the 90° angle bend, and in the contour of the armature end of the heelpiece.

On this single part, fifty-three specified dimensions are maintained and checked—many of which must be accurate to less than 0.002". Rigid tests and inspections safeguard the quality of the raw material itself—a very special sort of magnetic iron.

Care like this in the manufacture of each component makes it clear why Automatic Electric relays are the most reliable that money can buy.



Class "B" Relay, for outstanding endurance and dependability. *Write today for Bulletin 537.* Address: *Automatic Electric Sales Corporation, Northlake, Ill.* In Canada: *Automatic Electric Sales (Canada) Ltd., Toronto.* Offices in principal cities.

AUTOMATIC ELECTRIC

A member of the General Telephone System—
One of America's great communications systems

GENERAL SYSTEM

Circle 462 on page 19

STAINLESS STEEL "KNOW-HOW"
MAKES HUBBELL
MACHINE SCREWS
first choice for quality products
IT PAYS TO HAVE
HUBBELL
GOOD CONNECTIONS
REG. U.S. PAT. OFF.
PFLUEGER
THE GREATEST NAME IN TACKLE
"We want the very best screws possible... even though you may have to perform an unusual operation to do it."

The above statement is taken from the machine screw specifications of the Enterprise Mfg. Co., Akron, Ohio. It expresses their dedication to top quality, and it shows why so many other quality manufacturers, like Pflueger, are turning to Hubbell for their screw requirements.

This is particularly true in regard to austenitic chromium-nickel stainless steel machine screws, which require unusual manufacturing know-how. The ability, for example, to eliminate cracking which sometimes results from fabricating stresses; the ability to insure high tensile strength with maximum corrosion resistance; the ability to maintain pleasing appearance: all of these things are the result of long experience with stainless steel. In fact, Hubbell is the oldest company in the country making stainless steel machine screws.

This specialized knowledge is yours for the asking. For price and delivery information send blueprint or sample of the item.

HARVEY HUBBELL, INC.

HIGHEST QUALITY
WIRING DEVICES • MACHINE SCREWS

OVER 60 YEARS' EXPERIENCE in the manufacture of highest quality, rolled thread machine screws and special cold headed parts.

MACHINE SCREW DEPARTMENT BRIDGEPORT 2, CONNECTICUT

Helpful Literature

for quick analysis of vibration-caused problems has a response from 5 to 1000 cps. 4 pages. Consolidated Electrodynamics Corp.

Circle 660 on page 19

Packaged Drives

Horizontal, vertical, right-angle, open, enclosed, and alternating and direct current types are included in line of gearmotors and packaged drives detailed in bulletin DB-3650. Gearmotors, designed in accordance with AGMA classes I, II and III, range in speed from 7.5 to 780 rpm. Motor ratings are up to 75 hp. 8 pages. Westinghouse Electric Corp.

Circle 661 on page 19

Photoelectric Equipment

Supplement to Autotron catalog 57 covers new plug-in mounted photoelectric controls and light sources; miniature phototube and light source heads; and one-package photoelectric controls, impact-actuated electronic controls, current surge actuated controls and combined photoelectric and timing controls. 4 pages. Autotron, Inc.

Circle 662 on page 19

High Temperature Greases

Developed for high-temperature, slow-speed bearings, Dow Corning 41 silicone-based greases are becoming standard for uses ranging from worm-and-pinion sets to compressor engine injector valves. Brochure 6-206 describes properties and performance of these greases. 4 pages. Dow Corning Corp.

Circle 663 on page 19

Direct-Acting Valves

Installation dimensions, solenoid specifications and notes on applications on three and four-way direct-acting valves for 200 psi service are given in bulletin M-7. 4 pages. John D. Bachman & Co.

Circle 664 on page 19

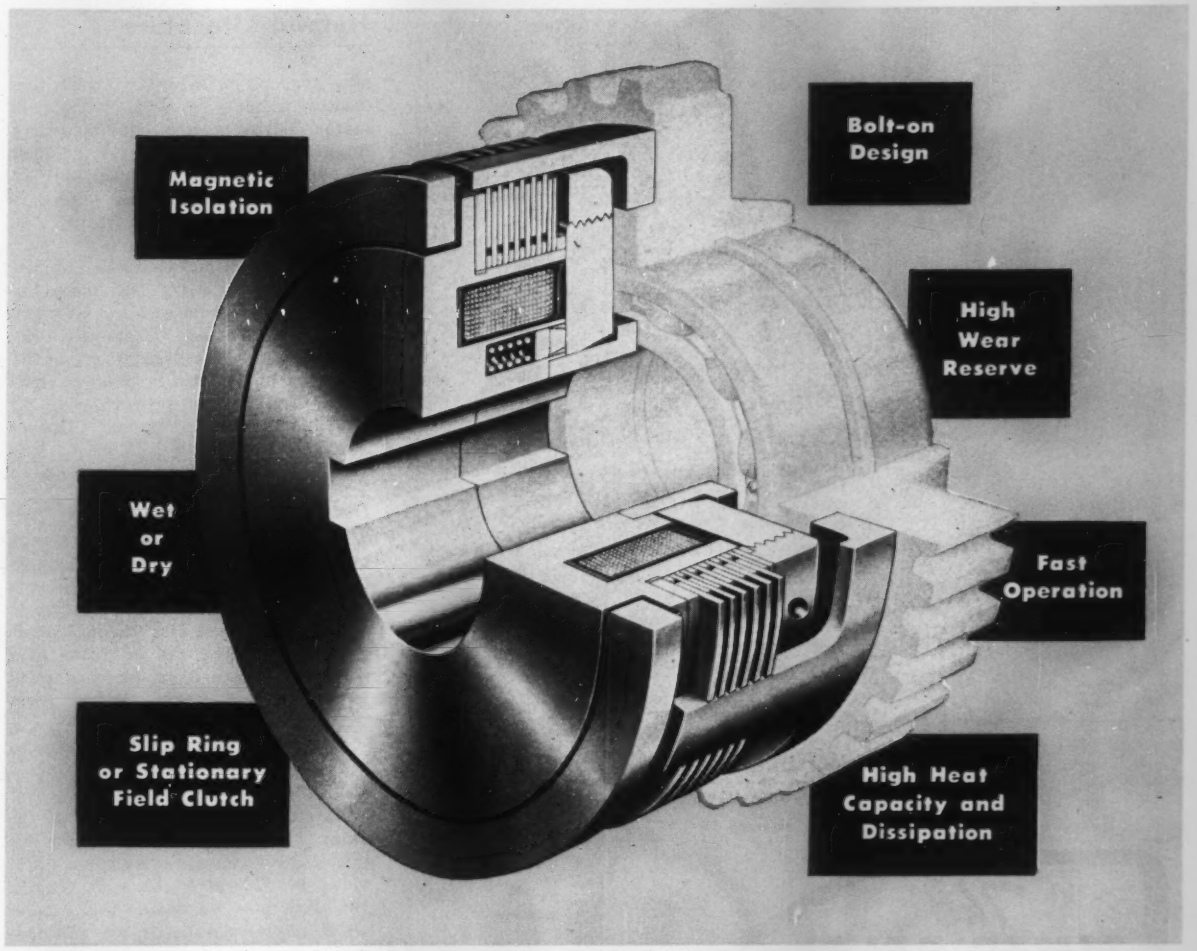
Industrial Motor

"Action" is title of folder describing the Actionator industrial motor, used to operate rotary, slip-stem and butterfly valves, dampers and other final elements in automatic control systems. Minneapolis-Honeywell Regulator Co.

Circle 665 on page 19

Motor Control Centers

"Unitrol-Cutler-Hammer Standardized Motor Control Centers" is title of catalog EL-174 which explains the



McCAULEY ELECTRO-MAGNETIC MULTIPLE DISC CLUTCH

BACKED BY 10 YEARS' EXPERIENCE

Here is an Electro-Magnetic Multiple Disc Clutch which has been used successfully for 10 years in Europe and now is manufactured in the United States.

Ten years of experience has proven that this clutch incorporates the basic requirements needed to meet the high standards of machine tool manufacturers.

MAGNETIC ISOLATION. The "magnetic flux" does not pass through the disc stack which assures non-magnetized discs resulting in low residual drag. Additional stray flux isolation is incorporated between the armature and mounting shaft.

SLIP RING OR STATIONARY FIELD CLUTCH. All clutch sizes are available in either slip ring or stationary field designs to meet the specific application requirements of small space, high torque, and high speed operation.

WET OR DRY. The friction material used allows the clutch to operate in wet or dry applications. This assures safe operation, under either condition, without the danger of mechanical damage or failure. The material is non-magnetic to further omit the stray flux path.

BOLT-ON DESIGN. Spider (drive cup) with mounting dimension made to customer specifications is included.

WEAR RESERVE. The high wear reserve is obtained by a large operating air gap for adjustment-free operation. An air gap adjusting nut is provided to set the basic torque value.

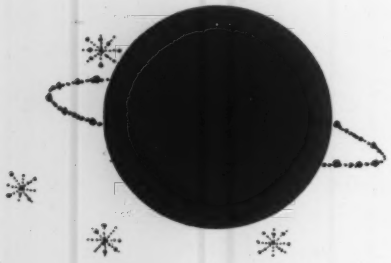
HEAT CAPACITY AND DISSIPATION. Discs are designed to prevent warpage even at high temperature. The high allowable disc temperature results in excellent heat capacity and dissipation characteristics.

FAST OPERATION. The low inductance of the electric circuit combined with special disc surfaces result in fast clutch operation.

McCauley Industrial Corporation also manufactures special Electro-Magnetic Clutches for applications which require non-standard clutches. Write for details.

McCAULEY INDUSTRIAL CORPORATION—Power Transmission Division
1840 Howell Avenue, Dayton 7, Ohio—MElrose 3541

Circle 464 on page 19



"Round and round," said Galileo

First with the telescope to discover Saturn's Rings, Galileo would no doubt marvel today at the all around perfection of Universal *Precision* Balls. Metallic or non-metallic materials—both are lapped to classic tolerances as fine as 0.000005 of an inch.

It's real round if it's a Universal Precision Ball.

UNIVERSAL QUALITY CONTROL—FOR ALL AROUND PERFECTION

Universal Ball co.

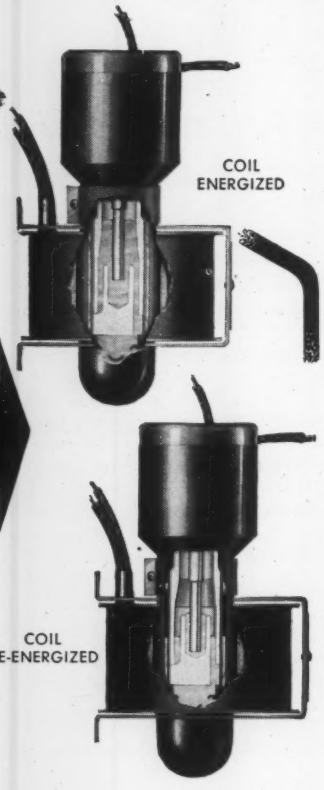
WILLOW GROVE, MONTGOMERY CO., PA.

Circle 465 on page 19

The
TIMER RELAY
that handles all controlled timing problems . . .

- ★ No false contacts
- ★ Non sticking
- ★ Practically "fail safe"
- ★ Low cost timer

Durakool®
STEEL MERCURY TIMERS



This steel clad, factory set, tamper proof Durakool timer-relay is practically non-breakable. Operating life multiplied 5 to 6 times by new plunger construction features. Combinations of operate-release time delays from 0.15 sec. to 20 sec.—either normally open or normally closed action.

See telephone directory for local distributor, or write.

DURAKOOL, INC.
ELKHART, INDIANA, U.S.A.
700 WESTON RD., TORONTO 9, CANADA

Circle 466 on page 19

Helpful Literature

new concept of modular design that makes possible a wide variety of motor control in a central structure. Suggested specifications are included. 32 pages. Cutler-Hammer, Inc.

Circle 666 on page 19

Leaded Alloy Steel

Heat treated, machine straightened, stress relived Elastuf PB leaded alloy steel was developed for fast machining properties. Analysis, advantages and mechanical properties are given in bulletin. A color chart guides selection of proper steels for machine parts. 4 pages. Horace T. Potts Co.

Circle 667 on page 19

Oscillographs

Five models of multichannel rack mounting oscillographs are descriptively covered in folder. Instruments allow simultaneous recording of up to eight phenomena in legible chart form. Recording can be made over frequency range from direct current to 100 cps. 8 pages. Brush Electronics Co.

Circle 668 on page 19

Galvanometer Recorder

Specifications and features of the Dual recti/riter two-channel rectilinear galvanometer recorder are provided in bulletin R-502. It records two functions on two 4½-in. scales on a single chart. It has 10-speed transmission. 6 pages. Texas Instruments Inc., Industrial Instruments Div.

Circle 669 on page 19

Asbestos Textiles

Selecting asbestos textiles for any application or temperature range is simplified by illustrated reference manual 76-327. Nontechnical booklet covers cloth, tape, tubing, lap, roving, cord, wick and rope, including 76 different nonmetallic and metallic cloths. 16 pages. Request on company letterhead from Union Asbestos & Rubber Co., 1111 W. Perry St., Bloomington, Ill.

Plastics Selection

Choice of the right plastic for any job by designers, engineers and fabricators is aided by revised 1957 "Condensed Reference File of Bakelite Plastics." Characteristics, fabricating techniques and other data on polyethylenes, vinyls, phenolics, styrenes, epoxies and polyesters are presented. 16 pages. Request on company letterhead from Bakelite Co., 30 E. 42nd St., New York 17, N. Y.

PRECISION "O" RINGS

Quality proved by all ASTM Tests

Precision "O" Rings made from Compound 830-70 meet or exceed all the SAE 120-R requirements for heat, oil resistance and other properties.

100% better compression set. Remarkable superiority in 300° F hot oil. 100% better Fatigue Test life.

For manufacturers of automobile, machine tool, farm equipment and similar equipment, Precision Compound 830-70 is your answer to positive long sealing life.

Have a sealing problem? You'll find the answer at Precision! There's a Precision engineer ready to help you.

Get your free copy of our engineering data sheet on Compound 830-70.

Specify Precision—first in Quality

Precision Rubber Products Corporation

"O" Ring and Dyna-seal Specialists

Box 431, Oakridge Drive, Dayton 7, Ohio **Canadian plant at: Ste. Thèrése de Blainville, Québec**

Circle 467 on page 19

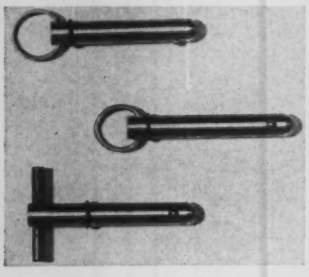
New Parts and Materials

Use Yellow Card, page 19, to obtain more information

Quick-Release Pins

lightweight units hold high shear loads

We-Pins can be used for any application where quick attachment and release are necessary. They are available in diameters from ¼ to 1 in., by sixteenths, in grip lengths from ½ to 4 in., and in three types of pull grip. Units hold shear loads from 3600 to 58,000 lb, depending upon diameter. Pull-out loads range from 10 to



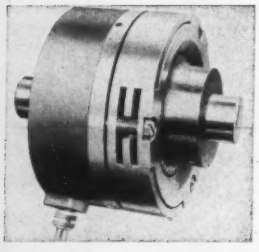
25 lb. Lock button is activated by silicone core. Pins resist fuels, oils, acids and solvents. They are stainless steel, plated chrome-alloy high-tensile steel, or carbon steel. **Waldick Engineering Co.**, P.O. Box 221, Garden City, N. Y.

Circle 670 on page 19

Electromagnetic Clutches

for wet and dry applications

Style GS and GSW electromagnetic clutches for dry and wet applications are fast-acting units which give smooth engagement and disengagement. They can be actuated remotely or directly with automatic or manual controls such as pushbuttons, limit switches or electric eyes. Direct magnetic action eliminates mechanical yokes and shifters. Oversized factory-



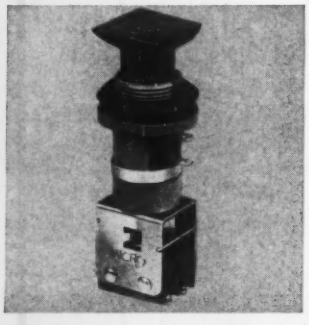
sealed bearings provide high capacity. Clutches are available in sizes from 0 to 9-in. diameter for operation with 12, 24, 90 or 115 v dc. **Stearns Electric Corp.**, 120 N. Broadway, Milwaukee 2, Wis.

Circle 671 on page 19

Pushbutton Switch

is small, lighted unit

Lighted pushbutton switch, designated 52PB51-T2, can be mounted on 1-in. centers, horizontally and vertically, and requires only 2⅛ in. below mounting panel. It has snap action and high force differential. Two subminiature single-pole, double-throw switching elements provide versatility of cir-



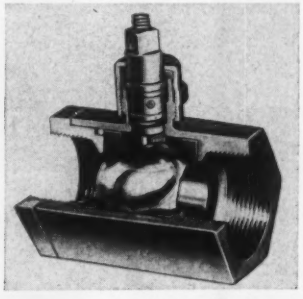
cuitry. Indicator lamp socket is fastened to outer body of switch and does not move when button is pushed. Terminals of indicator light are separate from those of switch, allowing indicator light to operate on any circuit desired. Translucent buttons are available in many sizes, shapes and colors. **Minneapolis-Honeywell Regulator Co.**, Micro Switch Div., Freeport, Ill.

Circle 672 on page 19

Ball Valves

for high-vacuum service

High-vacuum ball valves are available in sizes from ¼ to 6 in. in manually or air-motor operated models. Materials are bronze, aluminum, mild steel, 303 or 316 stainless steel, or polyvinyl chloride. Valves hold vacuum in either direction and permit



mounting in any position. One-quarter turn of stem provides rapid opening and closing, and permits precise throttling. **NRC Equipment Corp.**, 160 Charlemont St., Newton Highlands 61, Mass.

Circle 673 on page 19

Metal O-Rings

are gas-filled units

Pressure-filled metal O-rings have good sealing characteristics at elevated temperatures and provide increased resilience with greater flange deflection. Standard 0.010-in. stainless-steel rings are filled with gas at pressures from 500 to

Circle 468 on page 19→

"But I am constant as the northern star"

—Julius Caesar Act III Sc. 1

You know what to expect from CLARE Mercury-Wetted-Contact Relays—always. Their performance is CONSTANT.

Constant contact stability—No contact chatter—none at all.

Constant contact resistance—Repetitive measurements on individual relay contacts are constant to a few milliohms. Resistance of single contacts, including resistance of internal wiring between base terminals, ranges between 25 and 40 milliohms. Contact deterioriation cannot occur in this relay.

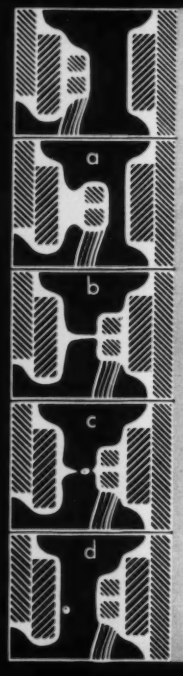
Constant operate time—Varies by only about 0.1 millisecond under constant drive conditions.

Constant pull-in current—Repetitive operating precision of given relay is within 1% of its minimum operating current. This precision is substantially independent of number of operations or ambient temperature.

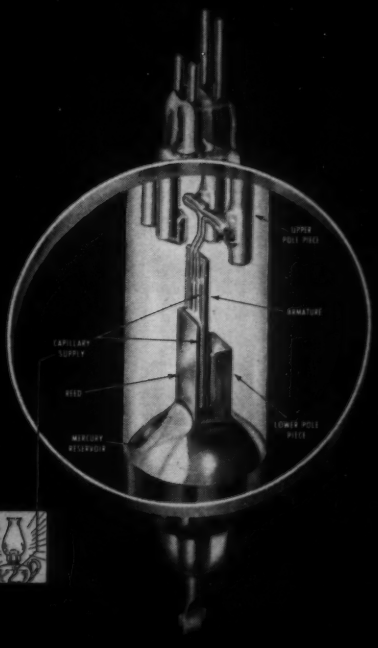
Constant adjustment—Requires no maintenance whatever. No possibility of change in adjustment. This remains true even after thousands of millions of operations.

If you have a job for which none but the best relay is good enough, it can cost you much more to settle for less than this CLARE RELAY. For complete information contact your nearest Clare representative or address C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare & Co., 659 Bayview Avenue, Toronto 17. Cable address: CLARELAY.

Send for CLARE Sales Engineering Bulletins Nos. 120 and 122



Drawings (left) from high-speed photographs show the cycle. (a) Filament of mercury forms between the contacts as they separate. (b) This becomes narrower in cross section and (c) finally parts at two points, allowing globule of mercury to fall out. Mercury flows up the capillary path, replaces amount lost, restores the equilibrium. (d) The momentary bridging of the parting contacts—and the extremely fast break that ends it—minimizes the arc and adds greatly to contact load capacity. Contact closure between the two liquid surfaces bridges mechanical bounce and prevents any chatter from appearing in the electrical circuit.



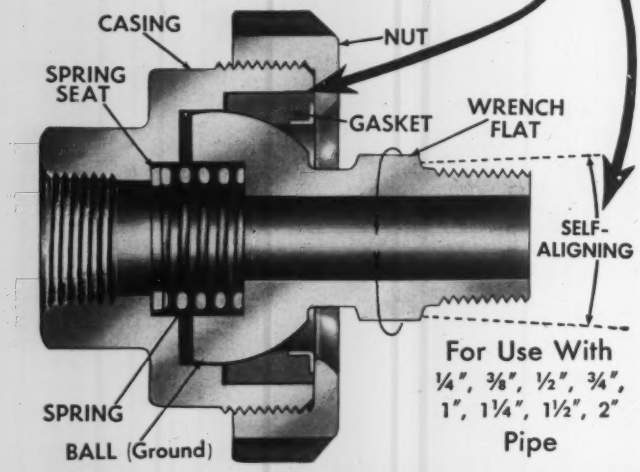
Contacts of CLARE Mercury-Wetted-Contact Relays are constantly renewed. By capillary action, like that of a lamp wick, a new film of mercury coats each contact with every make and break.

CLARE RELAYS

FIRST in the industrial field

TWO BIG ADVANTAGES!

1. Self-Aligning Ball
2. Chemically Inert Seal



BARCO SWIVEL JOINTS

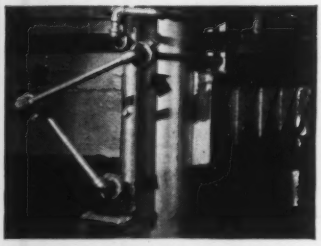
for STEAM, OIL or WATER LINES

Two important features give Barco Swivel Joints capabilities not found in ordinary swivel joints:

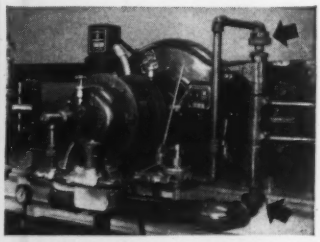
SELF-ALIGNING—Provides a wide tolerance for pipe fitting and machine alignment. Saves endless hours installation time and permanently protects against binding and wear.

CHEMICALLY INERT SEAL—Pressure sealing and automatically self-adjusting for wear. Ideal for steam service. Uniform performance over temperature range from −50° to +600°F. No lubrication needed.

Send for Catalog 265B, "Barco Self-Aligning Swivel Joints." Ratings as high as 750 psi steam or 3000 psi hydraulic. Sizes ¼" to 2"; angle or straight. *Ask for recommendations—Barco is at your service.*



PLATEN PRESS—Barco Swivel Joints (see arrows) in "dog leg" piping provide flexible connection to moving platen of press. Platen moves up and down. Line handles steam and cold water alternately.



OIL BURNER—Two Barco Swivel Joints (see arrows) mounted as pivot points on hinge provide swivel connections for fuel oil and steam atomizing lines to door mounted oil burner.

FOUNDED 1903 BARCO PRODUCTS BACKED BY EXPERIENCE

BARCO MANUFACTURING CO.
5061 Hough Street • Barrington, Illinois

The Only Truly Complete Line of Flexible Ball, Swivel, Swing and Revolving Joints
In Canada: The Holden Co., Ltd., Montreal

New Parts

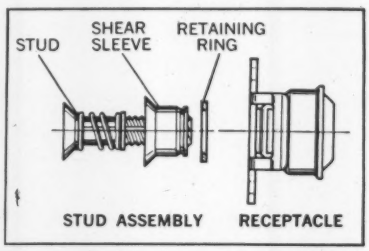
3000 psi at room temperature. Internal gas pressure offsets inherent loss of seal-metal strength at elevated temperatures. Principal use of the rings is in applications where operating temperatures exceed 1000 F, depending on variables of pressure and sealed material. Rings are available with variations in pressure filling, silver plating, Teflon coating and in special metals for specific requirements. **Advanced Products Co.**, 59 Broadway, North Haven, Conn.

Circle 674 on page 19

Stressed-Panel Fastener

withstands high shear and tensile loads

QAF quick-action stressed-panel fastener is for use on load-carrying panels in aircraft, guided missiles and other applications where quick access to service areas is required. It withstands high shear



and tensile loads, locks positively in less than one-half torque-free turn, and compensates automatically for sheet separation resulting from warpage or deformation in panels being secured. Fastener is vibrationproof and has tensile load capacity of 4000 lb in No. 1 size. It withstands operating temperatures to 550 F, and is available in ¼-in. diam stud size. Four stud lengths accommodate a total sheet thickness from 0.116 to 0.499-in. **Waldes Kohinoor Inc.**, 47-16 Austel Place, Long Island City 1, N. Y.

Circle 675 on page 19

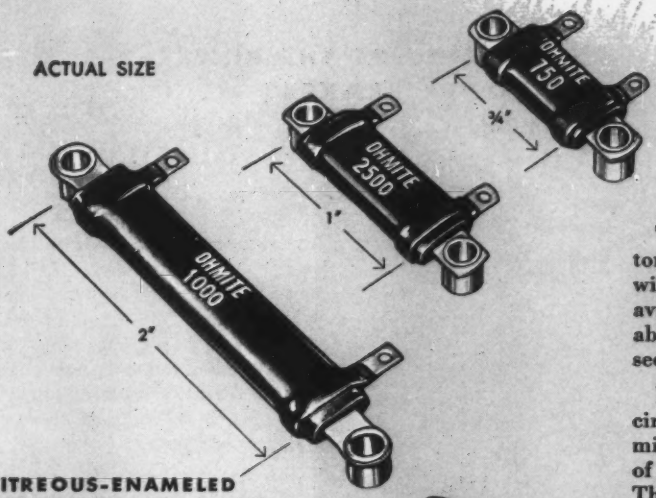
Induction Motor

has 1/300 to 1/50-hp ratings

Type-P single-coil, two-pole induction motor has a variety of applications, including operation of movie projectors, fans, gearmotors,

...pack higher wattage into less space with NEW MINIATURE OHMITE® THIN-TYPE power resistors

ACTUAL SIZE



VITREOUS-ENAMELED COVERING holds winding rigidly in place . . . protects winding from damage.

UNIFORM WINDING prevents "hot spots" and resultant failures.

STRONG, CERAMIC CORE provides a solid base for winding. Core unaffected by cold, heat, or high humidity.

INTEGRAL MOUNTING BRACKETS distribute heat more evenly throughout resistor and conduct heat away.

The new Ohmite *miniature* thin-type power resistors are now available in three wattage sizes in a wide range of resistance values; two wattage sizes are available from stock; also three wattage sizes available from stock in the standard thin-type resistor . . . see (*) table below.

Designed especially for use in modern electronic circuitry where space is at a premium, these new miniature units have all the timeproven superiority of standard Ohmite vitreous-enameled resistors. They are only 1/8" thick and 3/8" wide, and range in length from 3/4" to 2".

Because of their compact design, the new Ohmite *miniature* thin-type resistors pack higher wattage into less space. The stacking bracket allows mounting close to the surface and a hollow stud provides for convenient stacking of two or more units. The miniature thin-type rises only 11/32" above the mounting surface; stack mounted, four units are less than 1 1/8" in height. Shown in photograph are: (1) Standard Thin-Type Resistors with Unit Brackets; (2) Standard Thin-Type Resistor with Stacking Brackets; (3) Miniature Thin-Type Resistors.

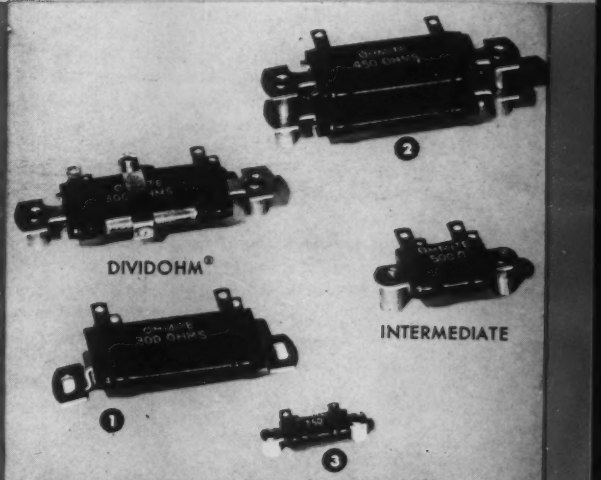
Write on company letterhead for Bulletin 138-B.

Watt Rating	Length of Core	Width of Core
MINIATURE THIN-TYPE RESISTORS		
* 10	3/4"	3/8"
15	1"	3/4"
* 20	2"	3/8"
INTERMEDIATE THIN-TYPE RESISTORS		
20	1"	13/16"
30	1 1/2"	13/16"
STANDARD THIN-TYPE RESISTORS		
* 30	1 1/4"	1"
* 40	2"	1"
* 55	3 1/2"	1"
65	4 3/4"	1"
75	6"	1"

Now available from stock . . .

2 miniature sizes: 10 and 20 watts

3 standard sizes: 30, 40, and 55 watts



WATTAGE RATINGS ARE BASED ON THE RESISTOR MOUNTED ON A HORIZONTAL STEEL PANEL .040" THICK BY 10" SQUARE. RATINGS SHOULD BE REDUCED APPROXIMATELY 15% FOR NONMETALLIC MOUNTING SURFACE.

BE RIGHT WITH OHMITE®

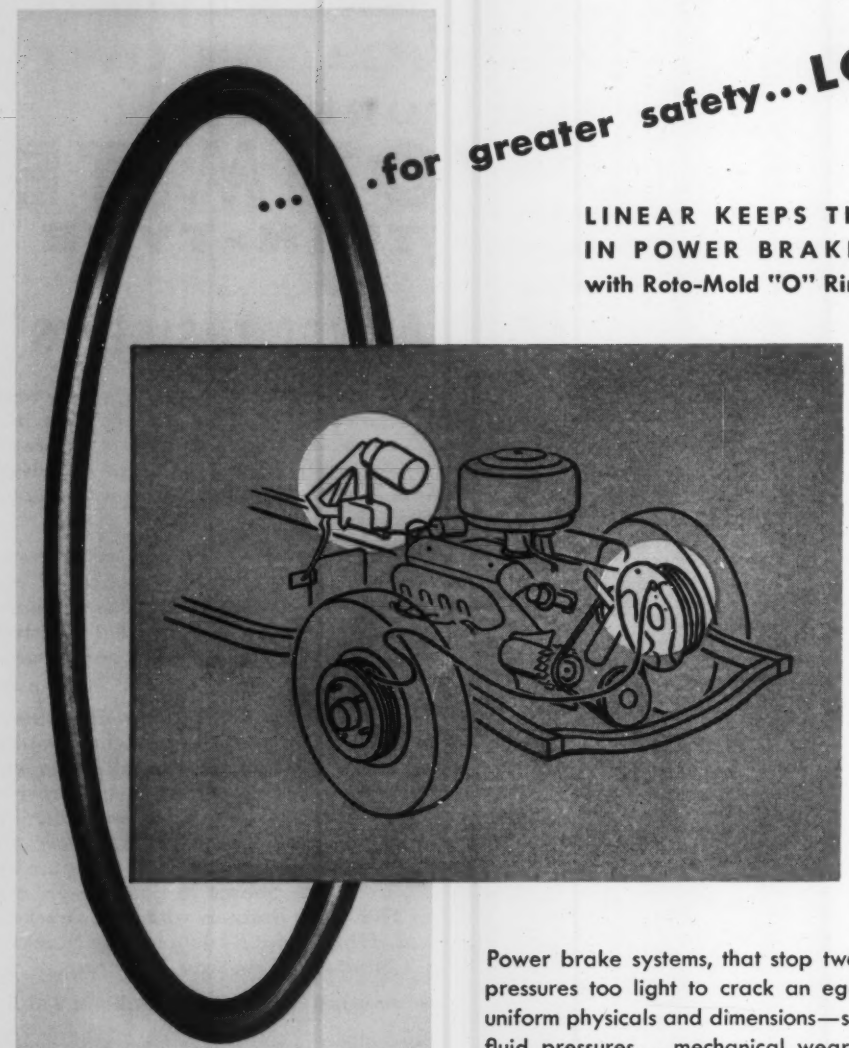
RHEOSTATS • RESISTORS • RELAYS • TAP SWITCHES • TANTALUM CAPACITORS

OHMITE MANUFACTURING COMPANY • 3618 Howard Street, Skokie, Illinois

Circle 470 on page 19

. . . for greater safety . . . LONGER

LINEAR KEEPS THE POWER IN POWER BRAKES
with Roto-Mold "O" Rings



Power brake systems, that stop two tons of automobile with pedal pressures too light to crack an egg shell, require lasting seals of uniform physicals and dimensions—seals that will withstand actuating fluid pressures . . . mechanical wear . . . abuse . . . chemical action of brake fluids and destructive action of improper hydraulic mediums.

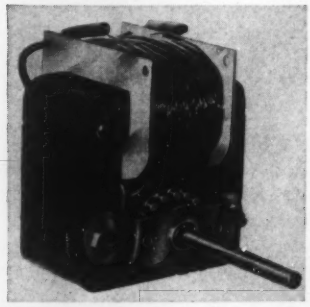
LINEAR'S ability to produce precision "O" rings in the most modern elastomers has helped solve a wide variety of sealing problems involving extreme ranges of temperatures (from −130° to 450° F), operating pressures up to 50,000 psi, and the corrosive action of silicate or phosphate esters, hydrocarbon or petroleum base fluids, or synthetic lubricants.

The exclusive Roto-Mold process assures top quality production . . . maximum economy . . . fast delivery schedules.

When it's a sealing problem, call on LINEAR or one of its agents for engineering assistance . . .
and be sure to specify LINEAR Roto-Mold "O" Rings.

"PERFECTION IN RUBBER"
LINEAR
LINEAR, Inc., STATE ROAD & LEVICK ST., PHILA. 35, PA.

Circle 471 on page 19



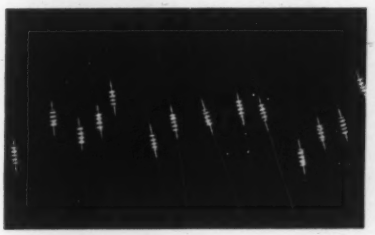
advertising displays, pumps and toys. It is available in various stacks and power ratings from 1/300 to 1/50-hp. Free speed is 3400 rpm; load speed is 3000 rpm. Unit is designed for 115-v, 60-cycle operation. **Heinze Electric Co.**, 685 Lawrence St., Lowell, Mass.

Circle 676 on page 19

Miniature Resistors

in 1/10-w size

Molded composition resistors in 1/10-w size have been added to a series of ½, 1 and 2-w Little Devil units. Resistors, 0.067-in. in diameter and 0.140-in. long, are for use in miniaturized assemblies where small size is necessary. Lead wires, molded solidly into resistance material, are hot-solder coated for rapid soldering. Units are available in RETMA values from



100 ohms to 1.0 megohm, ±10 per cent. **Ohmite Mfg. Co.**, 3631 Howard St., Skokie, Ill.

Circle 677 on page 19

Computing Amplifier

has accuracy of ±0.05 per cent

Model 808 transistorized parallel-summation computing amplifier accepts up to 100 different summations with equal accuracy. It is used for parallel voltage summa-

(*Continued on Page* 146)

What happens to mechanical parts under 5000-ampere surge?

There are techniques for measuring what happens electrically. But, what happens mechanically usually happens too quickly for the eye to catch.

The Milwaukee laboratories of Cutler-Hammer, Inc., use a Kodak High Speed Camera to solve such problems. Taking movies at speeds up to 3200 frames per second, the engineers capture on film the rapid sequence of events coincident with surge current. When the films are projected at normal speed, the action is slowed as much as 200 times. By studying the films, the engineers have been able to make improvements in the product, such as increased speed of response, higher ratings, better protection against motor burnouts under short-circuit conditions, and so on.

It's as simple as this: if your product or process moves too fast to see, slow the action down with high speed movies. Then you can often find the solution to product design and performance problems without tedious cut-and-try experimentation.

To see how others have used the Kodak High Speed Camera, to learn how it can work for you, write for the booklet, "High Speed Movies at the Service of the Engineer."

EASTMAN KODAK COMPANY, Rochester 4, N. Y.

the Kodak *HIGH SPEED* Camera

Kodak
TRADE MARK

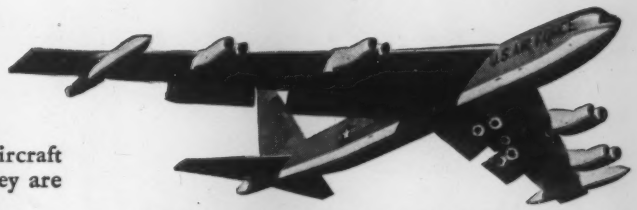
Circle 472 on page 19

Republic Makes the Steels for Flight

REPUBLIC

REPUBLIC STEEL

World's Widest Range of Standard Steels



TITANIUM IN THE BOEING B-52 saves 400 pounds in gross weight. Jet engine pods for this history-making, global bomber are fabricated by Bell Aircraft Corporation from titanium supplied by Republic and other producers. Titanium was selected for this application because of its lightness, strength, and corrosion-resistance. It offers the highest strength-to-weight ratio of construction metals. Titanium's extremely high corrosion-resistance makes it attractive for missile applications, such as fuel tanks. Nitric acid has little effect on titanium. It is immune to the corrosive action of salt water and sea air. Write for more facts.

Republic Steel is the world's largest producer of aircraft steels. And include guided missiles in aircraft. They are fast becoming a sizable steel consumer.

Steels furnished to the aircraft industry are as different as night and day. Requirements may individually call for strength, heat-resistance, corrosion-resistance, wear-resistance, high strength-to-weight ratio, ductility—or any combination of these factors.

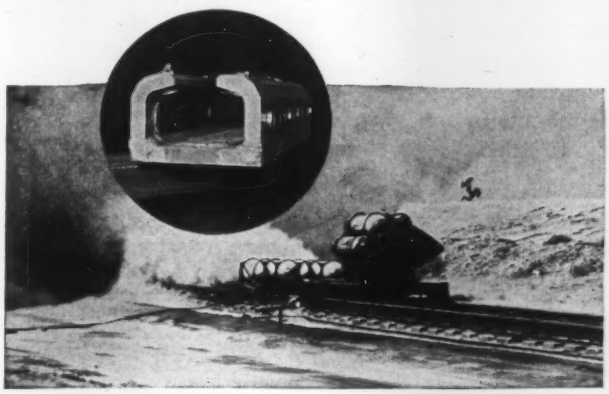
One reason for Republic Steel's prominence in this field is that Republic *makes a wide variety of the steels required.* Another reason is its metallurgical service teams—field, mill and laboratory metallurgists with years of experience gained through helping hundreds of designers and manufacturers solve problems similar to yours.

Now that the sound barrier has been passed and the next goal in sight is the "thermal thicket," material selection becomes even more important. To date two materials, titanium alloys and stainless steel, best qualify to meet high skin temperatures resulting from aerodynamic heat. Republic produces both of these metals in billets, hot rolled and cold finished bars, plates, sheets, and strip.

Republic Alloy Steels have played a prominent part in the development of operating and structural parts free from excess weight, yet tough and strong to withstand shock, impact, strain and vibration.

Our metallurgists and engineers are always available to work with your own personnel in using these Republic products to best advantage. The service is obligation-free and confidential. Send us the coupon if you would like metallurgical assistance.

ALLOY STEEL IN THE NORTH AMERICAN F-100 landing-gear struts provides strength, toughness, maximum resistance to fatigue. The struts are made by Bendix Product Division, Bendix Aviation Corporation. Exacting requirements for inner and outer cylinders resulted in the development of new grade of steel by Bendix and Republic metallurgists working in cooperation with North American engineers. This new steel, designated AMS 6427, was found ideal for application in the strength range of 220,000-240,000 psi. It maintains its great strength at wide temperature extremes. Republic metallurgists are available to help with your projects.



STAINLESS STEEL HELPS SPEED ROCKET SLED to world's record of 1560 miles an hour. The sled, designed and built by Convair Division of General Dynamics Corporation, is used in supersonic tests to evaluate the effect of rain erosion on aircraft and missile parts. The sled rides rails on slippers made of SAE 4130 Alloy Steel. Within each slipper (see photo inset) are stainless steel inserts, Type 321, of which Republic is a supplier. The inserts serve as a lubricant to reduce friction by shucking off metal particles at a temperature of 1500°F. The stainless inserts reduce friction so effectively that engineers no longer take it into account in calculations of sled performance.

STEEL

and Steel Products

REPUBLIC STEEL CORPORATION
DEPT. C-3689
3130 EAST 45TH STREET
CLEVELAND 27, OHIO

Please have a metallurgist call:
☐ Stainless ☐ Titanium ☐ Alloy

Send more information on these Republic products:
☐ Titanium ☐ ENDURO® Stainless Steel ☐ Alloy Steel

Name_____ Title_____

Company_____

Address_____

City_____ Zone____ State_____

Circle 473 on page 19

New

For Machine Tool Builders...

actual size

Dust-Splash Proof

ACRO

METAL CLAD SWITCH

SEALED PLUNGER

PLUNGER

ROLLER PLUNGER

ROLLER LEAF

Now the popular ACRO basic switch is available for many machine tool requirements in a new die cast aluminum housing. Seals out dust and liquids for longer life. Four types of actuators to meet your specific need. Flange or side-mounts in any position. Electrical rating: 15 amps., 115 volts A.C. or ¾ H.P.

Now ACRO and Robertshaw-Fulton Controls Company are working together to give you even better service on highest quality, competitively-priced switches. Write for complete information and application engineering help.

Mr. Controls®

Robertshaw-Fulton

CONTROLS COMPANY

ACRO DIVISION

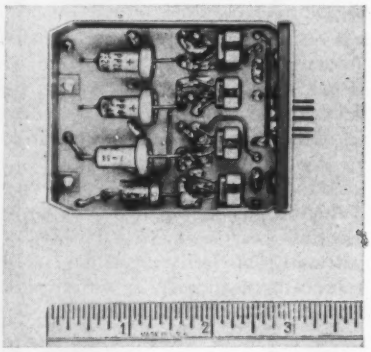
Columbus 16, Ohio

In Canada: Robertshaw-Fulton Controls (Canada) Ltd., Toronto

New Parts

(*Continued from Page* 143)

tion, for isolation of Mach 4 Mod O resolvers or equivalent, or as an isolation amplifier for any device providing 400 cps, analog ac voltage output signals. Accuracy is



±0.05 per cent; maximum output voltage (rms) is 22 v; phase shift is less than 0.15 deg. **W. L. Maxson Corp.,** Maxson Instruments Div., 47-37 Austell Place, Long Island City 1, N.Y.

Circle 678 on page 19

Gasketing Materials

permit seals at low flange pressures

Five Accopac high-density fiber gasketing materials permit seals at low flange pressures. Materials are for both low and high-temperature applications. They can be used in applications involving any type of fluid. Materials have densities from 60 to 82 lb, seal at pressures from 800 to 2000 psi, and have high torque retention. Binders include synthetic rubber, neoprene rubber and nitrile rubber. **Armstrong Cork Co.,** Industrial Div., Lancaster, Pa.

Circle 679 on page 19

Rotary Pump

for severe corrosive service

HCT All-Chem low-capacity, self-priming rotary pump of Hastelloy C handles capacities to 2 gpm, pressures to 50 psi and operates at 1750 rpm within temperature range of −200 to 300 F. Pump yields a linear flow, is reversible and can be staged for higher pressures. Equipped with Teflon impellers, bearings and packing, it is

Circle 474 on page 19

BUILT BY ENGINEERS

WHO SPECIALIZE IN

FLOW REGULATORS

Waterman Engineering Company has furnished thousands of flow regulators to all types of industries with growing satisfaction.

Their experience in this field is most valuable in accumulating a fund of data on flow control applications. Waterman offers you this experience in solving your flow control problems. Only a few of Waterman models are shown on this page.

Write for latest bulletin F

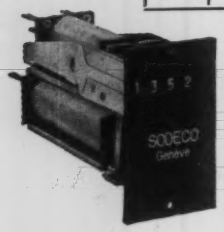
WATERMAN ENGINEERING COMPANY

725 CUSTER AVENUE • EVANSTON, ILLINOIS

Circle 475 on page 19

Designers like

✔ ELECTRIC RESET
✔ LOW POWER CONSUMPTION



OF
SODECO ELECTRIC IMPULSE COUNTERS

Sodeco Electric Impulse Counters can be operated in electronic circuits—their power requirements are so low. And, they offer immediate, remote electric reset. Small wonder they're the favorite of designers everywhere.

Designers also like—

SPEED Sodeco Counters count up to 25 impulses per second.

COMPACTNESS Model shown measures only 1⅜" x 2⅜" x 4⅜" and is suitable for flush mounting.

Sodeco Electric Impulse Counters are available in 4, 5 & 6 digit models, with secondary contacts, and either electrical or mechanical single-stroke toggle reset; or without reset.

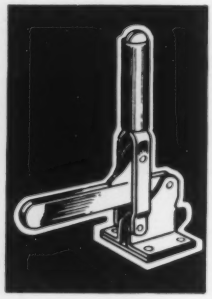
Write for full information on the Sodeco line.

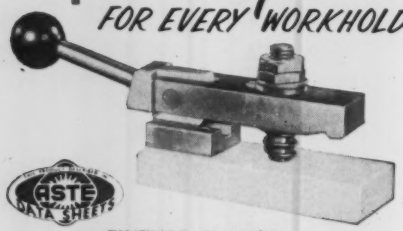
LANDIS & GYR, INC.
45 West 45th Street New York 36, N. Y.

Circle 476 on page 19

WESPO

THE *Right CLAMP*
THE *Right PART*
FOR EVERY WORKHOLDING JOB





ASTE DATA SHEETS

FIXTURE CLAMPS

Over 170 Styles and Sizes

WESPO fixture clamp assemblies save up to 70 percent on your designing and machining. They are standard with leading manufacturers.

TOGGLE CLAMPS and PLIERS

Over 80 types and sizes from ⅝" Midget to 12⅝" Clamp. PLIERS, from 1⅝ Jaw Midget to 4¼ wide Jaw.

Featuring REAMED HOLES, for better bearing — HARDENED BUSHINGS — SERRATED to prevent turning—HIGH TENSILE STRENGTH RIVETS for longer service.

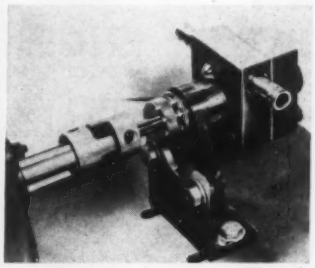
1,000 TYPES & SIZES OF COMPONENT PARTS

Write for Catalog of Toggle Clamps or Fixture Clamps & Parts

WEST POINT MFG. CO.
26941 W. 7 Mile Road • Detroit 19, Michigan

Circle 477 on page 19

New Parts



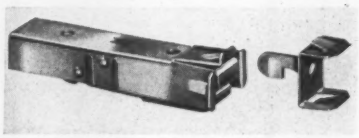
designed for severe corrosive service in laboratory and pilot-plant installations. Pump is available with pulley or variable drive, or as a base-mounted unit with electric or explosionproof air-motor drives. **Eco Engineering Co.**, 12 New York Ave., Newark 1, N. J.

Circle 680 on page 19

Latch

for metal cabinet installations

Tutch Latch opens cabinet door automatically with a touch of the hand, and holds door securely when closed. Installation in cabinet frame is accomplished by snapping latch housing into a pierced hole. Housing is rigidly held in place by outward tension against edge of mounting hole. Housing is for use in materials 0.026 to 0.032-in. thick and can be applied to cabinets after finishing. Strike works smoothly and quiet-



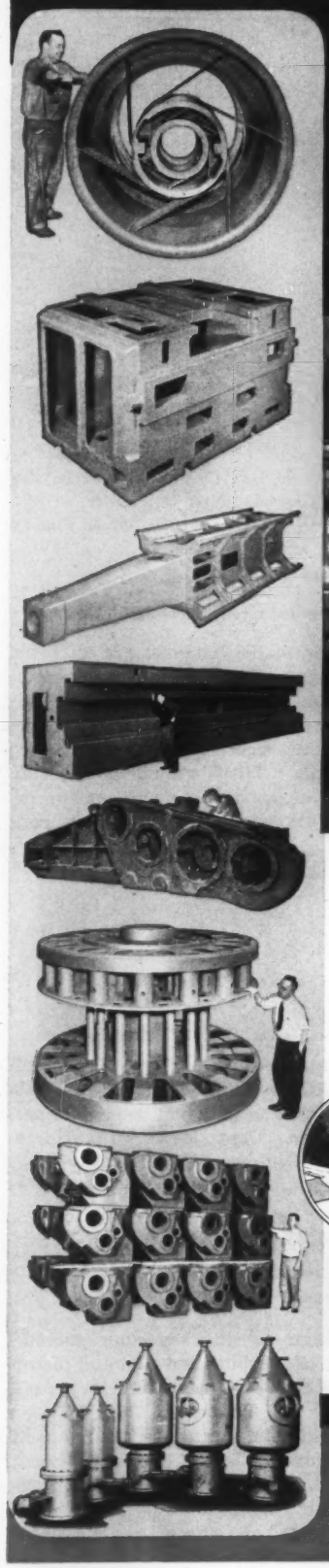
ly with latch. Unit is cadmium plated. It can also be installed in wood cabinets and furniture. **National Lock Co.**, Rockford, Ill.

Circle 681 on page 19

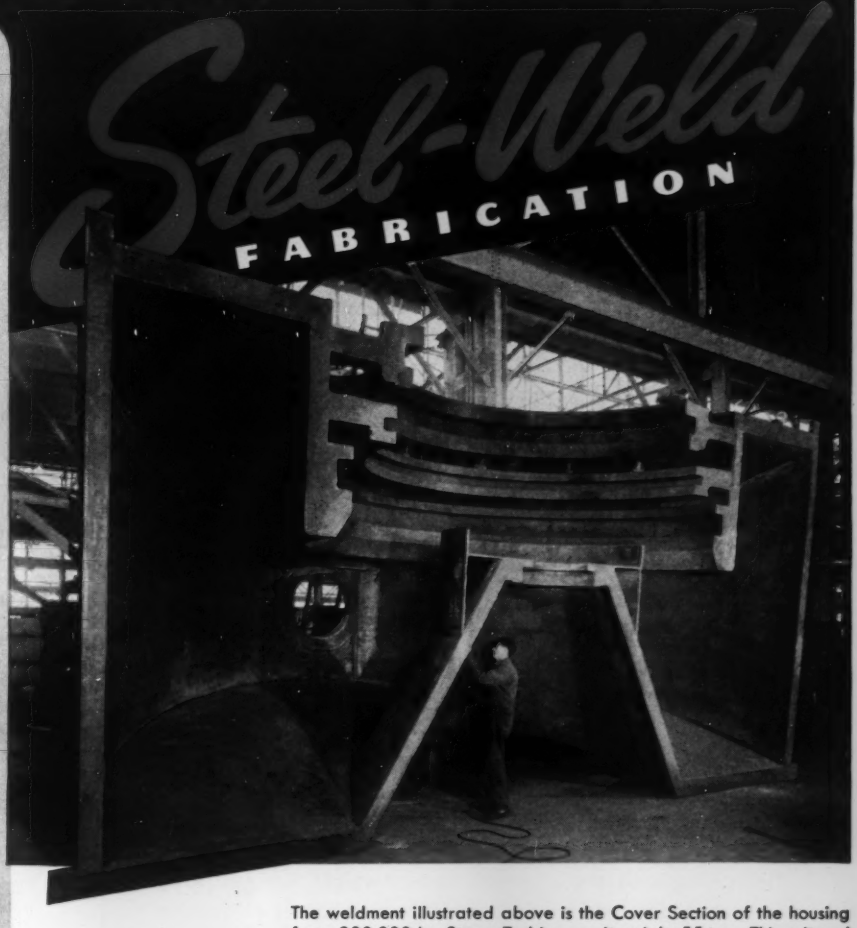
Miniature Relay

withstands high vibration and temperature levels

T-12 miniature dc-operated telephone-type relay features coined-hinge design for maximum efficiency and power and long operating life. Unit has cross-bar silver or palladium contact points and is available with resistive load ratings to 5 amp and pole arrange-



Steel-Weld FABRICATION



Use WELDED STEEL for Greater Strength with Less Weight!

The weldment illustrated above is the Cover Section of the housing for a 300,000 kw Steam Turbine . . . it weighs 55 tons. This unit and those shown at the left are typical of the thousands of Steel-Weld Fabricated parts and assemblies produced by Mahon each year for manufacturers of processing machinery, machine tools, and other types of heavy mechanical equipment. Are you taking full advantage of the economies offered by welded steel components in your products? In the design of almost any type of heavy machinery, or mechanical engineering project, there are parts and sub-assemblies that can be produced more economically and more satisfactorily in welded steel . . . because, in weldments you save time and pattern costs, and you get greater strength with less weight, plus the additional advantages of greater rigidity and 100% predictability. When you consider weldments, you will want to discuss your requirements with Mahon engineers, because, in the Mahon organization you will find a unique source for weldments or welded steel in any form . . . a fully responsible source with complete facilities for design engineering, fabricating, machining and assembling . . . a source where design skill is backed-up by craftsmanship which assures you a finer appearing product embodying every advantage of Steel-Weld Fabrication. See Sweet's Product Design File for information or have a Mahon sales engineer call at your convenience.

THE R. C. MAHON COMPANY • Detroit 34, Michigan

Sales-Engineering Offices in Detroit, New York and Chicago

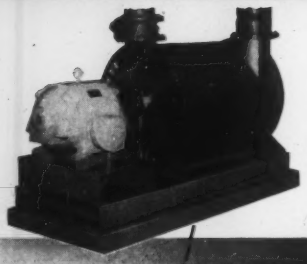
Engineers and Fabricators of Steel in Any Form for Any Purpose

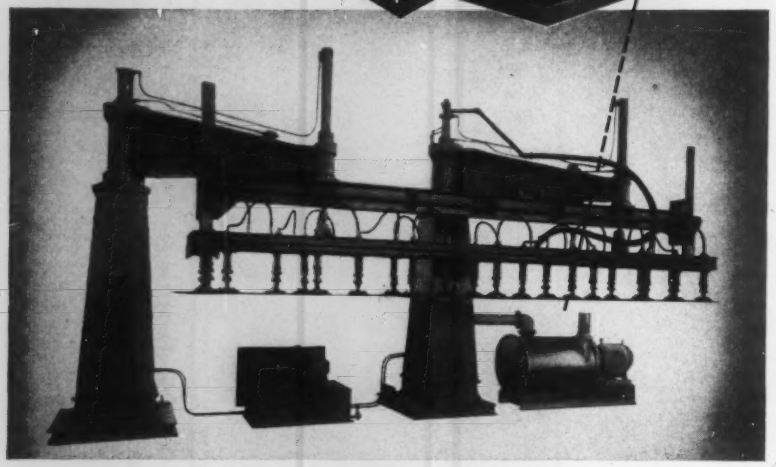
MAHON

Circle 478 on page 19

SPENCER Vacuum

Supplies the "Muscle" for this machine





Designers at W. S. Rockwell Co. had the problem of developing a machine which would pick up, move and deposit brass sheets of these specifications: weight — 880 lbs.; length — 24′; width — up to 42″; distance of movement — 4′ 6″.

It was decided that the most efficient method of pickup would be suction cup assemblies with vacuum. Obviously, the vacuum producer chosen must be extremely reliable and built to withstand continuous usage.

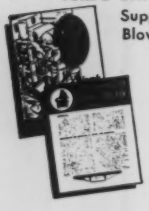
A 25 H.P., 4 bearing outboard type SPENCER unit rated at 435 CFM was selected to do the job.

Spencer will be glad to cooperate in designing and manufacturing vacuum producers or blowers to meet *your* special requirements.

Two Catalogs to Aid the Designer

"132 UNUSUAL USES OF SPENCER VACUUM"
Bulletin 144 illustrates and describes how Spencer Vacuum is used in industries from A to Z.

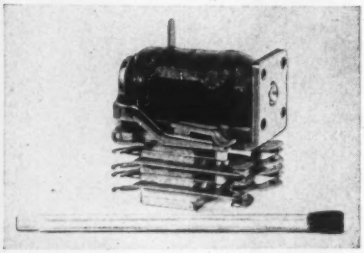
"TURBO DATA BOOK"
Supplies application data on Spencer Blowers. Request Bulletin 107-C.



STANDARD CAPACITIES
of Spencer Vacuum Producers
2 through 400 H.P.
Up to 12″ Mercury Vacuum
Volumes up to 17,000 C.F.M.

The SPENCER TURBINE COMPANY
HARTFORD 6, CONNECTICUT

ments to four-pole, double-throw. It meets specification MIL-R-5757B with high vibrational characteristics and temperature operation of 125 C. Relay is available in sev-



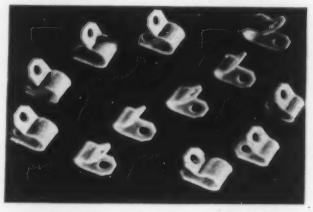
eral hermetically sealed enclosures. **U. S. Relay Co.**, 1744 Albion St., Los Angeles 31, Calif.

Circle 682 on page 19

Cable Clamps

are fabricated from Teflon

Teflon cable clamps are suitable for severe-service electrical installations. Clamps are chemically inert, nonadhesive and heat-resistant over wide temperature range. They resist weathering and seasonal change even in installations where direct and con-



stant exposure occurs. Clamps offer little friction, and water absorption is rated at zero. **Weckesser Co.**, Dept. MDC, 5701 Northwest Highway, Chicago 30, Ill.

Circle 683 on page 19

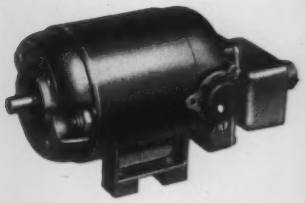
Sealed Cylinder

all-Teflon unit resists fluids

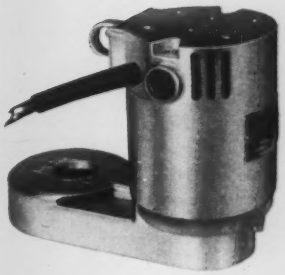
Design of this cylinder includes use of a tubing end seal and piston-rod bushing seal which permits use of Teflon sealing rings. Cushion-adjusting screw has self-regulating Teflon lock seal. Located in head or cap end, adjusting screw is directly opposite redesigned ball check and is interchangeable with it. Cylinder pro-

Circle 479 on page 19

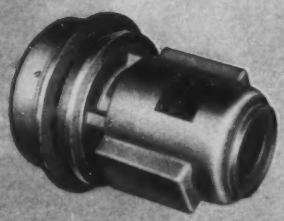
PASSES TESTS WITH FLYING COLORS



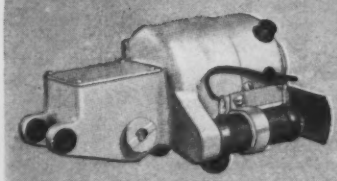
Aircraft de-icing pump motor.



Impact concrete drill motor.



Explosion-proof vacuum unit.



Gear motor for slow-speed drive.

If you are interested in any of the above motors write and we shall be glad to send full information.

. . . equal dependability for your product

One of the recent Lamb Electric developments is a motor to drive submerged pumps on military aircraft—for transfer of fuel from reserve to engine tanks.

For such an important application, motor reliability far beyond that normally called for was needed. To insure this degree of reliability in its actual operation of driving the submerged pump, test requirements for the motor were exceptionally rigorous.

As the result of advanced engineering and design, greatly increased brush life, and ability to operate at extremely high temperatures and withstand severe shock tests, the motor passed gruelling tests with flying colors.

The skill and experience exemplified here is available to your company to provide dependable power for *your* new or redesigned products.

THE LAMB ELECTRIC COMPANY • KENT, OHIO

A Division of American Machine and Metals, Inc.

In Canada: Lamb Electric—Division of Sangamo Company Ltd.—Leaside, Ontario

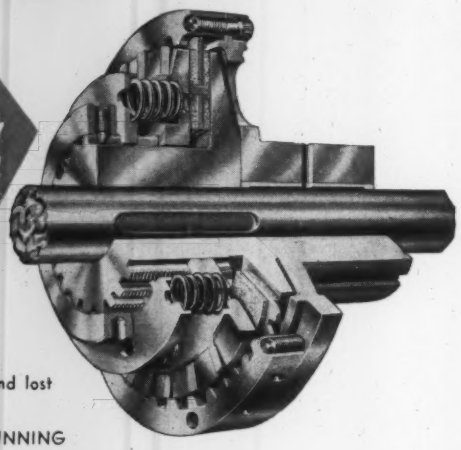
Lamb Electric

SPECIAL APPLICATION FRACTIONAL HORSEPOWER **MOTORS**

Circle 480 on page 19

HILLIARD *Clutches*
FOR POWER CONTROL DESIGN

ADJUSTABLE
Slip Clutch



- PROTECTS against overload, jams and down time.
- RESUMES THE DRIVE AUTOMATICALLY after overload.
- ELIMINATES SHEAR PINS and lost time.
- ADJUSTABLE - WHILE - RUNNING feature is available.

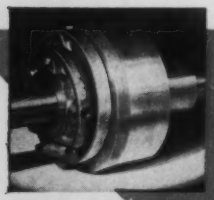
Hilliard Slip Clutches are continuously protecting the drive on dish washing machines—printing presses—packaging machines—case loaders—foundry equipment— air filters—conveyors—overhead doors—and many others.
They maintain steady torque while permitting speed variation on fabric drying drums, steel strip slitters and similar equipment.

The adjustable-while-running types are used to maintain constant tension on rewind stands for paper coaters, textile machines, rope, steel and wire mills and for drive systems requiring overload protection but which must be disconnected at times.

WRITE TODAY FOR BULLETIN 300 WITH COMPLETE INFORMATION.

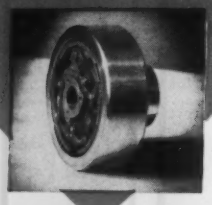
● OTHER HILLIARD CLUTCHES ●

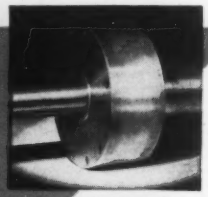
CONSIDER AUTOMATION - INVESTIGATE THESE PRODUCTS



SINGLE REVOLUTION CLUTCHES for automatic accurate control—electrical or mechanical—of intermittent motion, indexing, cycling and cut-off. Ask for Bulletin 239.

HILLIARD - TWIFLEX CENTRIFUGAL COUPLING for smooth, easy starting of any load automatically with overload protection and ability to accommodate shaft misalignment. Ask for Bulletin CE-3.





OVER-RUNNING CLUTCHES for automatic instantaneous engagement and release on two speed drives, dual drives and ratchet, or backstop action. Ask for Bulletin 231.

THE HILLIARD *Corporation*
MANUFACTURING CLUTCHES FOR OVER 50 YEARS

103 WEST FOURTH ST., ELMIRA, N. Y.

IN CANADA: UPTON • BRADEEN • JAMES, LTD.

Circle 481 on page 19

New Parts

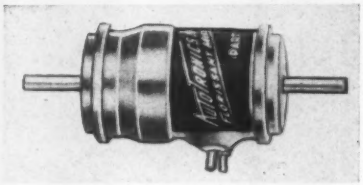
vides long seal life and freedom from fluid and temperature limitations of leather, synthetic rubber and composition sealing materials. Seals do not require changing when different fluids are introduced or high temperatures are encountered. **Flick-Reedy Corp.,** Miller Fluid Power Div., 2040 N. Hawthorne Ave., Melrose Park, Ill.

Circle 684 on page 19

Electromagnetic Brakes

are subminiature units

Four sizes of Type-B electromagnetic brakes are available for electronic and instrument applications. They are normally free running and output shaft is braked when energized. Small size, light weight and high performance make the units suitable for airborne applications. The servo-mounted units



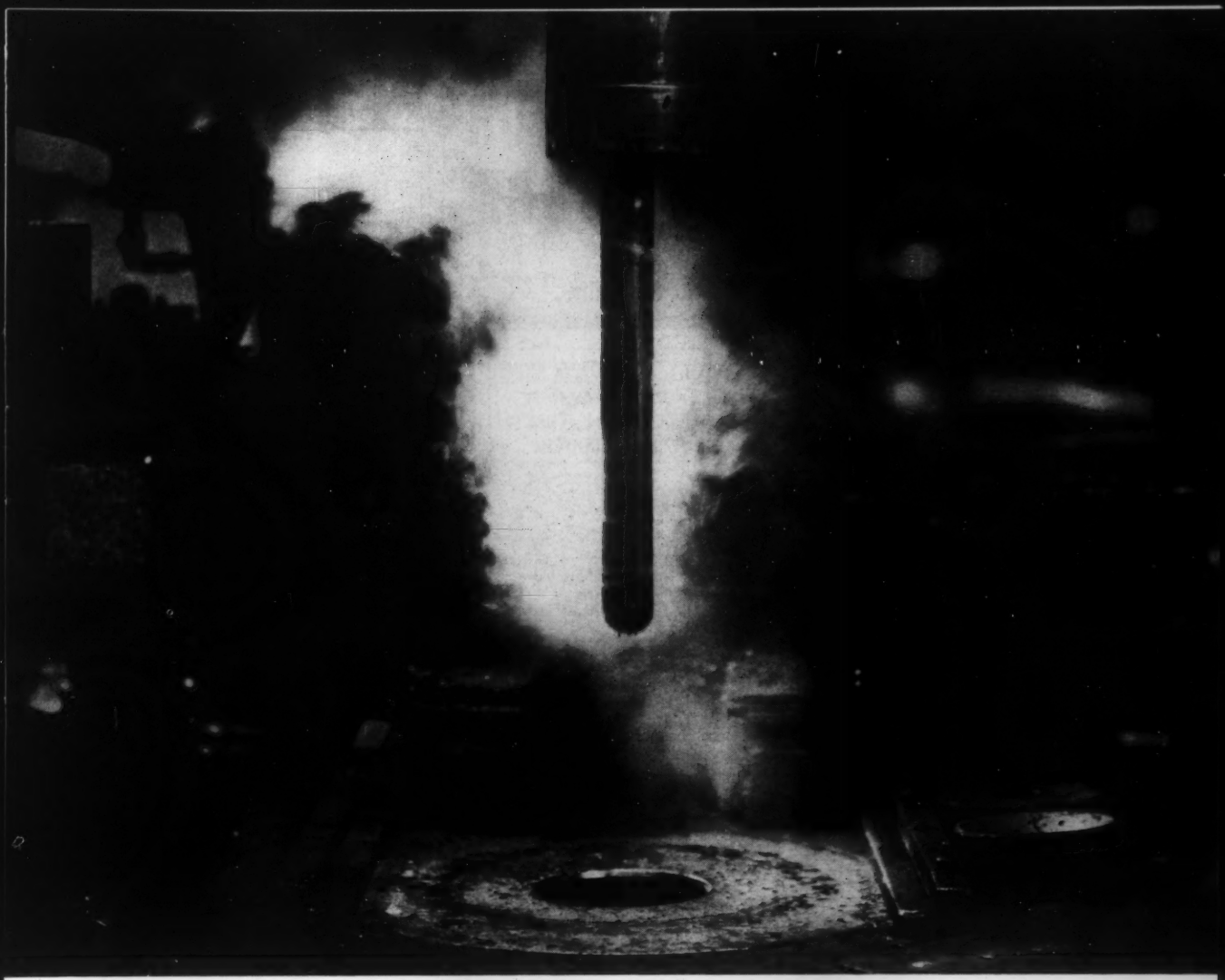
have shaft on either or both ends. Controlled torque output under vibration meets requirements of MIL-E-5272A. Units are available for inputs from 6 to 100 v dc. Brake torque (minimum) is from 4 to 64 oz-in. on the four units. **Autotronics Inc.,** Route 1, Box 812, Florissant, Mo.

Circle 685 on page 19

Photoelectric Relays

have high-power photocell

Type RPF photoelectric relays without amplifier tubes are designed around a new high-power photocell. They resist weather, dirt, vibration, shock, temperature, humidity and voltage fluctuation. Each unit operates directly from 100-130 v, 50/60-cycle line and controls its own internal relay. Smallest is Type RPF1, a general-purpose, nonadjustable unit which operates under low light intensity, is highly directional, controls 5-amp SPDT contacts rapidly, and is 4½ in. high. Type RPF3, the



Tough 2½" diameter mandrel at Rc 44 on 1150 ton brass extrusion press. Scovill Manufacturing Co.

Mandrel of HALCOMB 218 retains toughness and hardness at hot work temperatures...

This mandrel is made of Halcomb 218—a tough, air-hardening hot work steel. Halcomb 218 is suitable for tools like this which require a higher degree of toughness at moderately elevated temperatures than is obtainable with the tungsten types of hot work steels. And Halcomb 218 *retains both* its hardness and strength at these temperatures.

For example, at a hardness of Rc 44, Halcomb 218's Charpy Impact Strength is 33 ft-lbs at 500F. And it will retain this hardness after 1 hour, after 10 hours and even after 100 hours at temperatures up to 900F.

Properties like these cut tooling costs. The mandrel shown above is good for 1200 pushes, for example, and even then all it needs, usually, is repolishing before being used again.

Halcomb 218 is particularly useful for all hot work operations on which drastic coolants are used. It even resists breaking very successfully when water cooled in operation. If these sound like advantages you can use, call your local Crucible representative for more complete data. *Crucible Steel Company of America, The Oliver Building, Mellon Square, Pittsburgh 22, Pa.*

CRUCIBLE first name in special purpose steels

Crucible Steel Company of America

Canadian Distributor—Railway & Power Engineering Corp., Ltd.

Circle 482 on page 19

SAVE UP TO 30% ON MOTOR CORE COSTS WITH MOTORK®

Why use conventional laminations?...
MOTORK is dependable, economical and available.

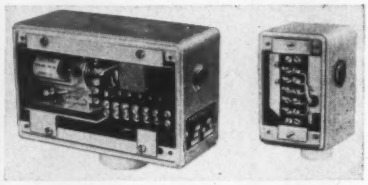
HERE'S THE COST STUDY YOU WANTED, P.J— STILL IN THE RED!
PRES.
THIS CALLS FOR ACTION!
MOTOR
GET THE MOTORK STORY FROM THE MAGNETIC METALS MAN...THAT'S YOUR ANSWER!
MOTORK'S PERFORMANCE CAN BE CHECKED 100% BEFORE GOING INTO PRODUCTION... NO REJECTS IN ASSEMBLY!
WE GIVE YOU THE MOTORK EVALUATOR ...CHECKS 'EM TO THE Nth DEGREE!
MOTORK LAMS
MOTORK PRODUCTION SCHEDULES ARE FLEXIBLE AND DEPENDABLE. THAT MEANS HIGHER PRODUCTION... LOWER INVENTORIES IN YOUR PLANT!
SPECIFY MOTORK!
QUALITY STANDARDS ALLOW DESIGNS TO BE HELD TO CLOSER LIMITS... REDUCES YOUR UNIT COSTS!
I'M SOLD!
I'M SMART!
I'M MOTORK!
PRES.

Cost studies show savings of from 10% to 30% through using MOTORK laminations rather than the conventional type of laminations in motor core assemblies; let us quote on your motor lamination requirements . . . you will find the savings impressive.

MAGNETIC METALS COMPANY

ELECTROMAGNETIC CORES and SHIELDS
HAYES AVENUE AT 21st STREET • CAMDEN 1, N. J.

New Parts



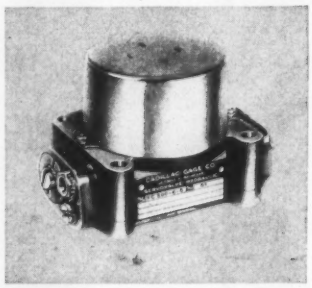
largest unit, is adjustable from outside, operates from 1 ft-c, and is sensitive to a 10 to 20 per cent change in illumination. **Photobell Co. Inc.**, 43 Vesey St., New York 7, N. Y.

Circle 686 on page 19

Servo Valves

are electrohydraulic flow-control units

Three models of FC200 two-stage electrohydraulic servo valves are for use in high-performance aircraft and missiles. They utilize a closed-loop hydraulic control circuit to position the output stage, and are of balanced push-pull construction. Output stage controls rate of flow of fluid to an actuator, and consists of matched spool and sleeve which form a precision four-way valve. Valves incorporate a



single large-capacity filter element to protect the control stage. **Cadillac Gage Co.**, P.O. Box 3806, Detroit 5, Mich.

Circle 687 on page 19

Angle Bracket

permits fast driving of screws

Speed Nut angle bracket, designed primarily for storm-sash use, has applications in picture framing, metal doors and windows, cabinets and display cases, or wherever extruded channel sections must be mitered or butted. Fastener is narrow in width. Re-

Circle 483 on page 19

Circle 484 on page 19→

DOW CORNING CORPORATION

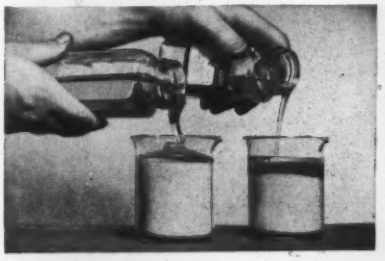
Silicone News

FOR DESIGN ENGINEERS No. 41

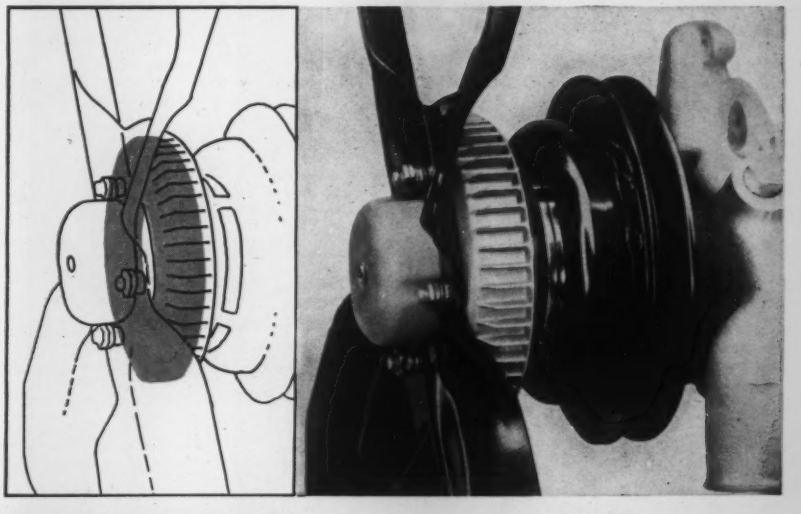
NEW SILICONE INSULATING RESINS FLOW FREELY WITHOUT SOLVENTS

Two new free-flowing, solventless silicone electrical resins are now available from Dow Corning in commercial quantities. Identified as R-7501 and R-7521, these 100% silicone resins are ideal for impregnating or encapsulating miniature and subminiature motors, transformers and other electrical and electronic assemblies.

Since both new resins pour freely, they quickly saturate and fill all voids in even the most complex assemblies, thus eliminating the problem of insulation punctures caused by escaping solvent gases. As shown in the photo, Dow Corning R-7521 is more fluid at room temperature and penetrates much deeper into 20-40 mesh sand than a conventional epoxy resin.



Both of the new resins cure to a strong, bubble-free mass having excellent dielectric properties, good thermal conductivity and high moisture resistance. When cured, they readily withstand continuous service at 400 F ambients and intermittent exposure to temperatures up to 500 F. (Cont. Pg. 2)



NEW MERCURY GETS "POWER BOOST" WITH THE HELP OF SILICONE FLUIDS

A thermostatically controlled hydraulic coupling on the engine fan is effecting a "Power Boost" of up to 17 hp on the 1957 Mercury automobile. It does so simply by basing the speed of the fan on engine coolant temperature rather than engine speed.

Identified as a "Thermo-Modulated Drive" by its manufacturer, the Schwitzer Corporation of Indianapolis, the unit was designed in conjunction with Mercury's Engine Engineering Office.

The coupling is made up of two mating faces separated by Dow Corning 200 Fluid. At coolant temperatures below 160 F, the distance between faces plus the viscosity of the fluid combine to keep the fan speed down to less than a quiet 1500 rpm.

Should engine temperatures approach the 190-200 F range, however, thermostatic control brings the coupling faces closer, the fluid achieves better traction and the fan picks up speed. But at 2600 rpm or so, fan speed again becomes constant.

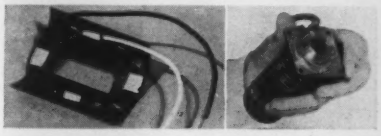
As a result, fan horsepower requirements are held to a minimum and fan noise is all but entirely eliminated. Figure 1 on the next page illustrates the fan-to-engine speed ratios and the horsepower savings offered by the Schwitzer "Modulated Drive".

Schwitzer has also developed a straight "Modulated Drive" coupling without the thermostatic control feature. This unit is being used by several automobile manufacturers in connection with their air-conditioned models, in which the cooling and power requirements of the engine and the air conditioner may be effectively balanced against each other. (Cont. Pg. 2)

Silicone Glass Coil Insulators Reduce Motor Assembly Costs

By insulating the coils of their ⅓ hp, 14,000 rpm afterburner ignition actuator motors with silicone-glass laminates, Lear, Inc., have cut costs a substantial $1.50 per unit.

Located next to jet engines where ambient temperatures soar to 400 F and higher, these motors have always been silicone protected. Lear originally tape-wrapped the coils by hand, but they recently eliminated this time-consuming job by switching to pre-formed glass laminates bonded with a Dow Corning silicone resin.

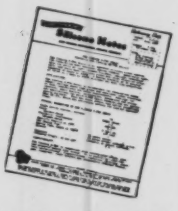


By reducing assembly time to an absolute minimum, the laminated insulators save Lear $1.50 per motor while still providing the maximum in insulating efficiency. The coil insulators are pre-formed in two sections by Stevens Products of East Orange, New Jersey. *No. 416*

Silicone News

DOW CORNING CORPORATION

DOW CORNING PUBLICATIONS ON NEW DEVELOPMENTS AND TECHNICAL DATA . . . .



Documentary film "What's a Silicone?" available free of charge for showings to technical audiences in every industry. In full color and sound, this dramatic 16 mm film allows you to see Dow Corning Silicones in action improving the performance of products ranging from nursing bottle nipples to diesel locomotives. For more information about this educational film and how to arrange a showing for interested persons in your plant, circle ---------- *No. 420*

"Effects of Radiation on Organopolysiloxanes," a research paper reprinted from Industrial and Engineering Chemistry, describes the effects of secondary radiation from 4 different sources on organopolysiloxanes. Sources include cyclotron radiation, cobalt — 60 gamma, electron, and X-ray. Results indicate that siloxanes containing large amounts of phenyl substitutions may be good construction materials around high energy radiation units. *No. 421*

Two new low-shrink silicone rubbers, Silastic 2067 and 2068 can be fabricated in molds designed for organic rubbers. Both have low compression set and good strength; are serviceable from —70 to +500 F. For data sheets on each, circle ---------- *No. 422*

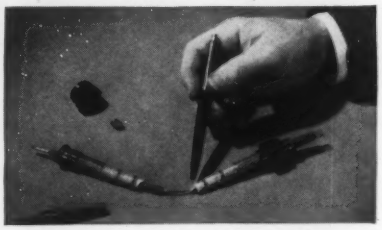
"What's a Silicone?" is the title of a 32-page booklet which answers that often asked question in semi-technical terms. Indexed and illustrated, this booklet has earned an international reputation as the most interesting and informative description of silicones ever published. *No. 423*

Dow Corning 41 Grease, for equipment operating at temperatures from zero to over 500 F, is described in a recently published brochure. Included are properties, typical applications, and case histories illustrating the practicality of 41 Grease in many different industrial applications. *No. 424*

Silastic — in mechanical applications — increases life and serviceability of original equipment; reduces maintenance and downtime. A completely new brochure gives properties and cites applications and case histories to help you use this versatile silicone rubber to best advantage in your application. *No. 425*

SILASTIC WITHSTANDS HIGH TEMPERATURE, HIGH VOLTAGE ON SPARK PLUG LEAD ASSEMBLY

Selecting a rubbery insulating material that would withstand up to 15,000 volts at 400 F in aircraft spark plug lead assemblies posed no problem for design engineers at Scintilla Division, Bendix Aviation Corporation, Sidney, New York. Already familiar with Silastic*, the Dow Corning silicone rubber, they knew it has excellent resistance to moisture and retains good mechanical and dielectric properties even after prolonged exposure to heat and high voltages.



Actually, Scintilla uses Silastic in four different areas on the new Bendix lead: for the inner and outer layers of the cable; for the molded terminal insulators; and as an interlayer to separate the three courses of braided metal sheathing. Interlaying the braided sheathing with Silastic not only keeps moisture out, but protects the sheathing against vibration to give it longer life.

The new Silastic insulated lead is now standard for the Wright turbo compound 18 cylinder, 3350 hp engine that powers the DC 7, the Super Constellation and various military aircraft. *No. 417*

*T. M. REG. U. S. PAT. OFF.

SILICONE FLUIDS *(continued)*

Reliability of Schwitzer couplings is assured by the use of Dow Corning 200 Fluid as the driving member. Conventional organic oils would thin out with increased temperature and become too viscous in cold weather, completely changing the characteristics of the coupling from those required. On the other hand, Dow Corning 200 Fluid retains a near constant viscosity over broad temperature spans and also eliminates maintenance problems. In tests, this silicone fluid shows no sign of gumming, sludging, or varnish after the equivalent of an estimated 100,000 miles on the road. *No. 418*

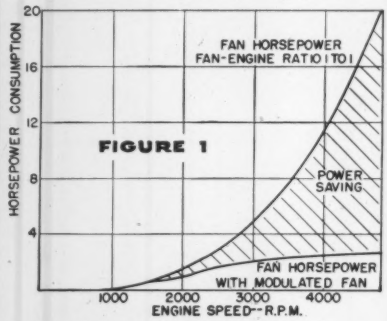


FIGURE 1

NEW SILICONE RESINS *(continued)*

At room temperature the viscosity of R-7501 is 2500 centistokes and the viscosity of R-7521 is 100 centistokes. Either resin may be thinned by warming to 175 F. If desired, the resins can be blended together to obtain any intermediate viscosity.

The resins are cured by adding a peroxide catalyst and heating at temperatures up to 390 F. Shelf life of the uncatalyzed resins is well over a year; pot life of the catalyzed resins at room temperature is over six months. Dow Corning R-7501 and R-7521 can be used as received or combined with a wide range of inorganic fillers. *No. 419*

Dow Corning Corporation, Dept. 6820, Midland, Michigan

Please send me: 416 417 418 419 420 421 422 423 424 425

NAME _____

TITLE _____

COMPANY _____

STREET _____

CITY _____ ZONE STATE _____

SILICONE NEWS is published for product design and development engineers by

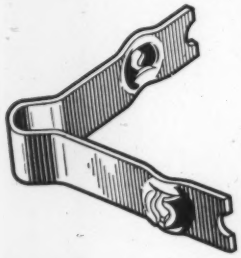
DOW CORNING CORPORATION
MIDLAND MICHIGAN

first in silicones

DOW CORNING SILICONES

ATLANTA BOSTON CHICAGO CLEVELAND DALLAS DETROIT LOS ANGELES NEW YORK WASHINGTON, D. C.
CANADA: DOW CORNING SILICONES LTD., TORONTO GREAT BRITAIN: MIDLAND SILICONES LTD., LONDON FRANCE: ST GOBAIN, PARIS

lieved corners on clip allow for heavy burrs on sawed edges of extrusions and provide flexibility to offset hole misalignment. Countersunk impressions in each end of



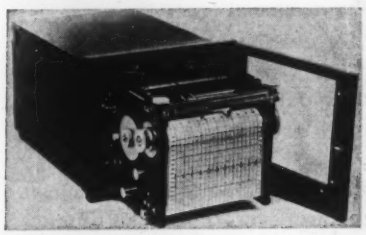
part permit dimpling of thin metal sections for flush or flat-head screws. **Tinnerman Products Inc.,** P. O. Box 6688, Cleveland 1, O.

Circle 688 on page 19

Recording Potentiometer

is miniature two-pen unit

Recording potentiometer is equipped with two pens which write margin-to-margin on a single five-in. strip chart, producing two continuous records in a small space. Accuracy on each pen is 0.5 per cent. Recorder is available with one front-set limit switch



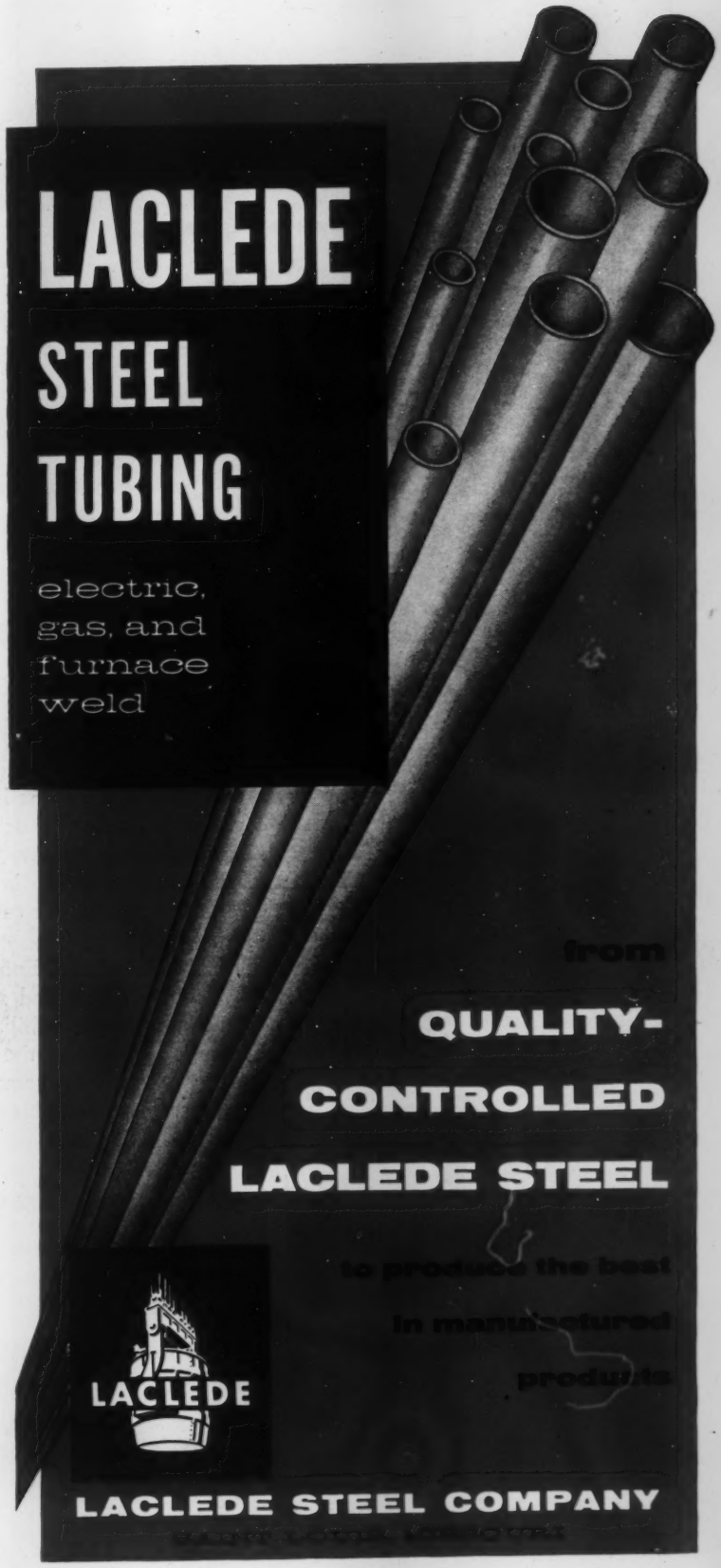
and three back-set limit switches on each pen. Amplifiers are completely transistorized. **Westronics,** 3605 McCart, Ft. Worth, Tex.

Circle 689 on page 19

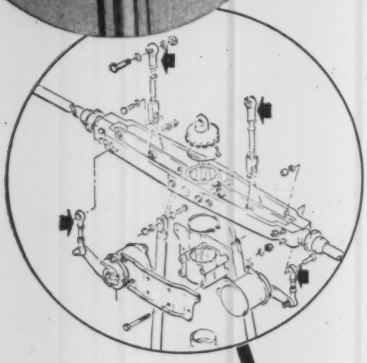
Permanent-Magnet Motor

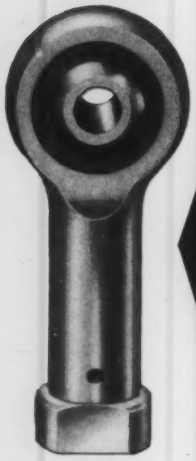
is miniature unit with governor attached

Model PM-OG miniature permanent-magnet motor with governor is for use in recorders, actuators, blowers, and similar units. It develops a maximum of 1/400-hp with speeds varying from 5000 to 20,000 rpm. Torque is 0.20 oz-in.



Circle 485 on page 19





THE NEW "BELL RANGER" HELICOPTER USES HEIM UNIBAL ROD ENDS

Model 47-J is the latest helicopter to be introduced to the commercial market by Bell Helicopter Corp., and has been named the Bell Ranger. It is a four-place, executive type machine with a deluxe interior or a series of quick-change cabin arrangements for cargo, litter, and internal hoist configurations.

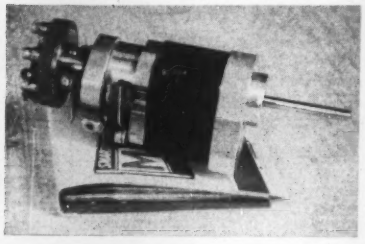
HEIM Unibal Rod Ends were chosen for the linkages in the carburetor heat and mixture control installations, and in the main rotor stabilizer bar assembly. The rods link hydraulic dampers to the bar, which provides exceptional stability to the flight characteristics of Bell helicopters, acting like a gyroscope and, through mixing levers, keeps the rotor plane of rotation in its pre-established flight path.

THE HEIM *Unibal* is the spherical bearing which corrects misalignment in every direction because of the universal movement of the ball — Reduces friction and lost motion in linkages — Eliminates the effects of vibration — Lowers assembly costs because of its quick and easy installation — Carries heavier loads.

Perhaps Heim can help solve — or simplify — your linkage problems. Feel free to write. Be sure each engineering and purchasing department has a Heim catalog.

THE HEIM COMPANY / Fairfield, Connecticut

Circle 486 on page 19



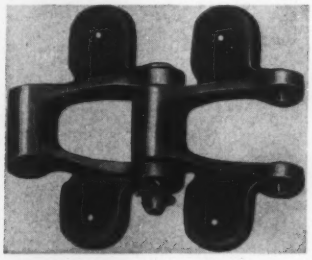
and current draw is 0.2 amp. Motor is available in voltages from 6 to 28 v dc. It provides fast starts at temperatures as low as − 55 C, quiet operation and reversibility. **Small Motors Inc.**, 2076 Elston Ave., Chicago 14, Ill.

Circle 690 on page 19

Conveyor Chain

withstands hard wear and shock

Forged-steel, pin-type conveyor chain withstands hard wear and shock. Simple design permits easy assembly and disassembly. Each pin is locked against rotation. Each link has a wing attachment, permitting attachment of wood or metal conveyor slats for all types of duty. Chain can be used in single or multiple



strands, and is available in standard pitches. **Robert A. Main & Sons Inc.**, 257 Pascack Rd., Paramus, N. J.

Circle 691 on page 19

Flow Control

for back-flushing operations

Flush-Flo control, when connected into a line, permits controlled flow rate in one direction and uncontrolled flow rate with minimum pressure drop in other direction. For use in equipment requiring back-flushing operation, unit is

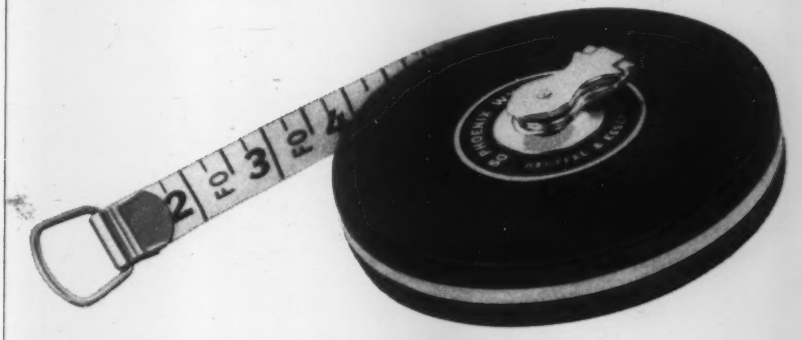
(*Continued on Page* 162)

ALBADURE*... the steel tape with lasting legibility

Here is a steel tape that stays clear and legible long after markings on other tapes have worn off.

An amazingly tough plastic coating on both sides of the line protects the white background, the graduations and numbers on ALBADURE tapes, giving their surfaces tremendous resistance to abrasion and corrosion. To quote a State surveying party report, "If ALBADURE stood up in this tough mud and sand, it'll stand up anywhere." Available in all standard lengths, widths and graduations, in cases and on reels.

PHOENIX WYTEFACE®... the woven tape that outlasts others 3-1



PHOENIX WYTEFACE (non-metallic) Woven Tapes made from extra strong synthetic yarns, are harder wearing, with higher tensile strength and dimensional stability than ordinary woven tapes. A special plastic coating on both sides protects the line against hard use, water, stones or brush.

The end of the line is enormously strengthened by a lamination of Flexi-Foam, a spongy plastic-rubber. No stitches or hinge point to weaken the line.

A Highway Engineer reported of the non-metallic PHOENIX WYTEFACE, "It has at least three times the life of an ordinary metallic tape." *Ask Your K & E Dealer!*

*Trade Mark

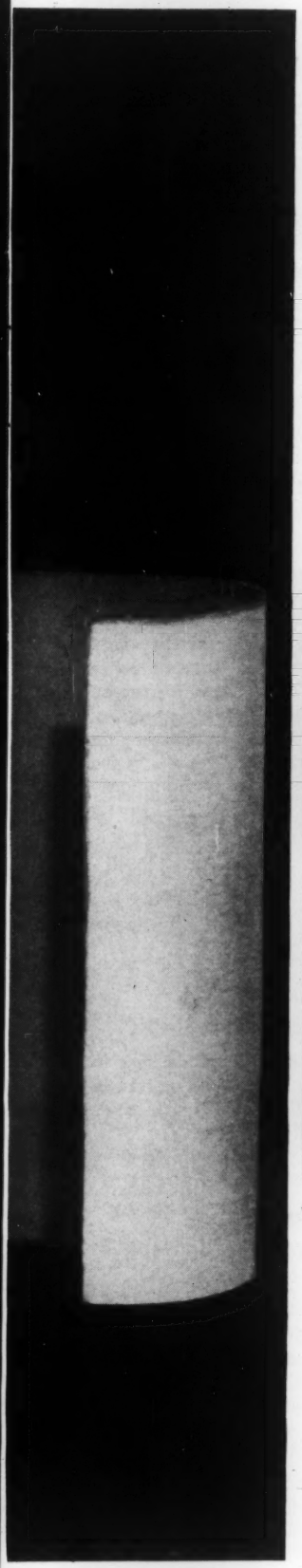
89 YEARS OF LEADERSHIP In equipment and materials for drafting, surveying, reproduction and optical tooling . . . in slide rules and measuring tapes.

KEUFFEL & ESSER CO.

NEW YORK • HOBOKEN, N. J. • Detroit • Chicago • St. Louis • Dallas • San Francisco • Los Angeles • Seattle • Montreal

Circle 487 on page 19

BASO INC.,
GOT RUSTPROOF, GASTIGHT VALVES
WHEN THEY SWITCHED
TO ALCOA ALUMINUM
SCREW MACHINE
STOCK



Baso Inc., pioneered the thermoelectric controls that make wonderful things happen in America's homes. Gas ranges, clothes dryers, heating units turn themselves on and off automatically.

Brass was formerly used for Baso valve cocks, but these parts were converted to aluminum in conjunction with a complete switch to aluminum for valve bodies. This change entirely eliminated any corrosion problem that might occur between dissimilar metals. With one pass of a single-point tool, Baso gets a surface finish of 16 micro inches in a cycle time of 18 seconds (machine capacity). The lapping operation required with brass was eliminated and so were gaskets, for the metal-to-metal aluminum seal proved to be gastight.

If you machine parts from steel or brass, now is the time to take a hard look at these economic facts about aluminum:

1. Aluminum costs less than brass, and machines just as fast.
2. Aluminum machines faster than steel and won't rust.
3. Aluminum scrap allowance is high.

Now is the time to switch to Alcoa® Aluminum. To help you make that switch, call on your nearest Alcoa sales office. For immediate delivery of screw machine stock, contact your nearest Alcoa distributor. ALUMINUM COMPANY OF AMERICA, 873-H Alcoa Building, Pittsburgh 19, Pa.

IN DESIGN

Russell Matthews, Director of Product Engineering (left), discusses aluminum backing for valve facing with James Dowd, Director of Industrial Engineering. Mr. Matthews says, "Alcoa helped us start redesigning with aluminum back in 1948. Our conversion from brass is now complete."

IN PURCHASING

Mr. G. C. Winters, Director of Purchasing, says, "We have never had to reject Alcoa stock either from the mill or from its local distributor. We find both very cooperative in making deliveries to meet production schedules, thereby saving us warehouse space."

Visit the Alcoa-National Acme Cooperative Machining Demonstration, National Acme Company, Cleveland, Ohio, September 10, 1957

ALCOA ALUMINUM SCREW MACHINE STOCK

WE CHOSE ALCOA ALUMINUM SCREW MACHINE STOCK

✻ LEARN WHY OTHER COMPANIES HAVE *SWITCHED TO ALCOA ALUMINUM*

Direct quotes from leaders in industry on why they buy from Alcoa. Fill out coupon for your copy.

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Company_____

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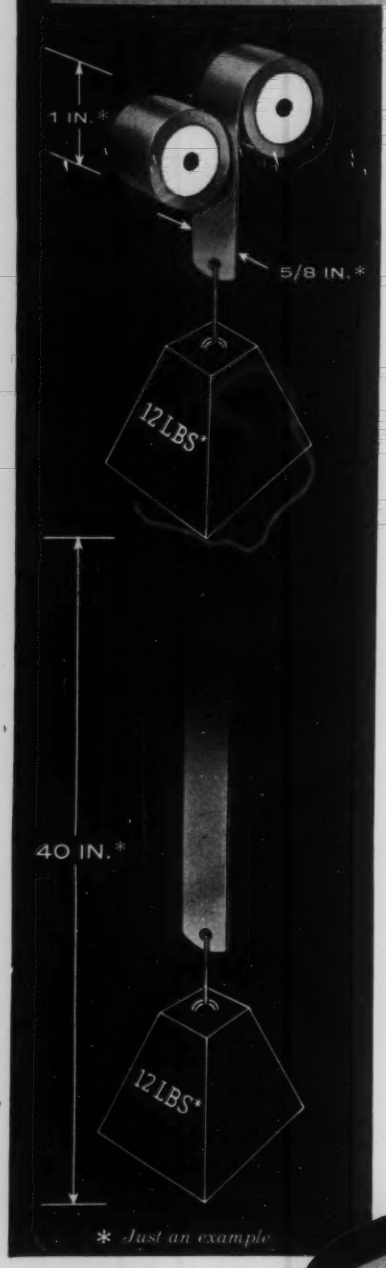
Circle 488 on page 19

BALANCE IT *with a*
NEG'ATOR® *constant-force spring*



NEG'ATOR is the name of a new kind of spring—the coiled-band spring that extends many times its original size without the increasing force common to conventional springs.

One of the natural uses of the NEG'ATOR Spring is counterbalancing without mass—vertically as illustrated, or horizontally. Using the NEG'ATOR Spring, the design engineer can eliminate dead weights or linkages and gain space, freedom of motion, reduced over-all weight, simplified assembly.

For example, each of the NEG'ATOR Extension Members used back-to-back in the illustration measures about 1 inch in diameter when coiled. They will counterbalance a 12 lb. weight over about 40 inches of travel. The only force required to move the weight is that required to overcome friction in the mechanism. There is no inter-coil friction in the NEG'ATOR Spring.

NEG'ATOR Springs in extension or motor form are versatile in counterbalancing functions—are now being used to balance light tank floats in sensitive liquid-level indicators and fire doors and other heavy equipment. Extensions range to over 20 feet.

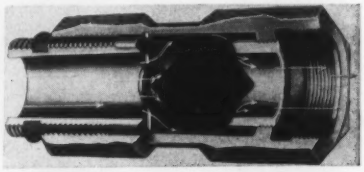
Used as an extension spring, a motor, band, clamp, or clip—this revolutionary new *constant-force* component upsets all previous spring principles, opens a whole new field of mechanical design by doing what springs have never done before.

These and other functions of Hunter NEG'ATOR constant-force springs are described in Bulletin 310N, "The Story of the NEG'ATOR Spring." Send for a copy.

HUNTER SPRING COMPANY
3 Spring Avenue, Lansdale, Pennsylvania
SPRINGS • STAMPINGS • TEST APPARATUS

New Parts

(*Continued from Page* 159)



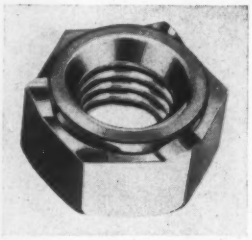
available with controlled flow rates to 8 gpm. Parts are bronze, neoprene and nylon. **Hays Mfg. Co.,** Industrial Sales Div., 853 W. 12th St., Erie, Pa.

Circle 692 on page 19

Weld Nuts

in pilot and recessed types

Pilot-type weld nut, shown, automatically locates itself in hole punched in subassembly. Pilot also forms a positive barrier between threads and weld, preventing weld-spatter on threads. Recessed type nut has a recess around hole to eliminate clogging of nut by weld flow or spatter; no retapping is required. Both types are available with or without lock-



ing feature which provides lock in middle of nut. **MacLean-Fogg Lock Nut Co.,** 5535 N. Wolcott Ave., Chicago 40, Ill.

Circle 693 on page 19

Overload Control

has adjustable load limits

Load Sentry electromechanical fail-safe overload control is for use where overload of any kind can be registered on an electric motor. It is built around positive action of a contact meter-relay, and has no electron tubes. Unit combines accuracy, continual indication of motor load, and adjustable load limits. Maximum load to be permitted on motor being monitored

Circle 489 on page 19

FROM THESE SIMPLE, BASIC PARTS

ANY COMBINATION FITTING YOU NEED

New IDEAL SIMPLET UNIVERSAL FITTING

open-face bodies and hub-covers—easily assembled in seconds

- RUGGED, DURABLE MALLEABLE IRON
- MEET J.I.C. AND N.M.T.B.A. STANDARDS
- HUBS REVISED WITHOUT REPLACING FITTING
- LARGER WIRING AREA
- COVERS SUPPLY HUBS FOR CONDUIT — NO NEED TO DRILL
- PRECISION TAPERED PIPE THREADS
- MOUNTING LUGS, CONDUIT STOPS
- LIQUID, DUST, LINT PROOF

Ideal-Simplet introduces this revolutionary advance in conduit fitting design with the *new* Universal Fitting. It provides an almost infinite variety of hub combinations for practically any wiring job!

With only *five* basic body sizes and a wide choice of covers, every practical style and type of fitting with multiple hubs can be assembled in a matter of seconds. Your fittings inventory and overall costs can be substantially reduced. Standards, "specials" and even seldom-used styles are available immediately from stock!

It would pay you to get the facts about this new Ideal-Simplet Universal Fitting, NOW!

SEE YOUR WHOLESALER . . . or send coupon →

Pioneers in conduit fittings and electrical specialties

IDEAL

SIMPLET FITTINGS, Inc.
A Subsidiary of Ideal Industries, Inc.
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Name_____

Company_____

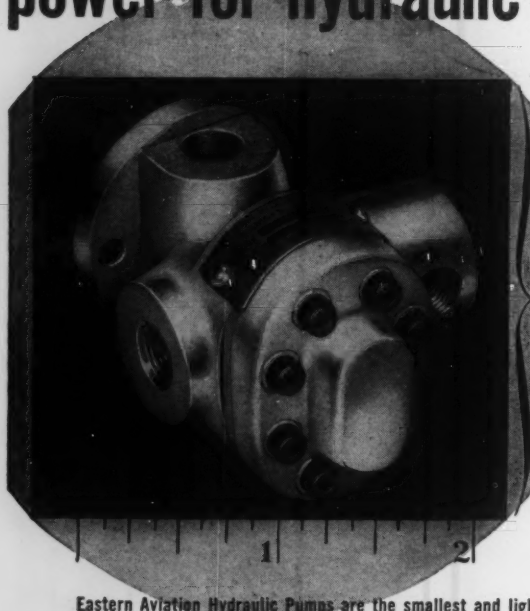
Address_____

City_____ Zone____ State_____

Wholesaler's Name_____

Circle 490 on page 19

power for hydraulic systems



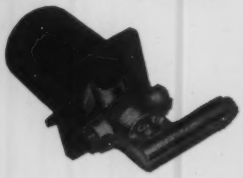
comes in small packages

Eastern Aviation Hydraulic Pumps are the smallest and lightest line of pumps ever made. They supply as much as one gallon of fluid per minute against pressures as high as 2000 PSI.

The 1700 Series of high speed gear pumps have theoretical displacements varying from .0091 to .1089 cubic inches per revolution. This series of pumps can be close-coupled directly to various electric motors. They are made in many configurations with and without integral bypasses. A variety of bearing combinations handle different types of fluids and operating pressures.

Eastern engineers can adapt and design hydraulic pumps to meet your specifications. On your next project, contact Eastern for engineering help that really helps.

Eastern 1700 SERIES PUMPS



1733-HBU-249

1731-LCU-205

1781-HBV-255

1700 SERIES PUMP

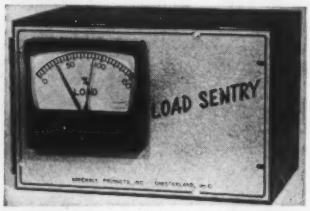
Send for Aviation Bulletin 340

Eastern INDUSTRIES, INC.

100 SKIFF ST. • HAMDEN, CONN.

Circle 491 on page 19

New Parts



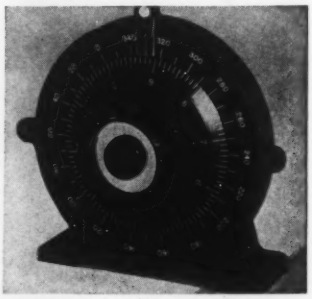
is set by adjustable pointer anywhere on dial of meter-relay. Dial has 30 divisions from zero to 150 per cent of normal load. Units for a wide range of amperage are available, differing only in transformers. **Assembly Products Inc.,** Wilson Mills Rd., Chesterland, O.

Circle 694 on page 19

Dial Assemblies

concentric units added to breadboard parts line

Two concentric dial assemblies have precision-machined cast-aluminum housing which insures rigidity. Aluminum inner dial face is designed for low mass and inertia, and plastic index marker can be set at 0, 90 or 270-deg positions for convenient reference. Dial assembly BP-302-36 is a ¼-in. shaft unit with ratio of 36:1. It permits readings to accuracy of 3 minutes. BP-302-100 model has ⅛-in. diameter shaft, ratio of



100:1, and provides reading accuracy of better than 2 minutes. **Beckman/Helipot Corp.,** Newport Beach, Calif.

Circle 695 on page 19

Phenolic Tubing

has high internal burst strength

Phenolite Grade XX-3113 is small-diameter, paper-base phenolic tubing for high-strength, press-fitted mechanical and electrical assem-

NEW

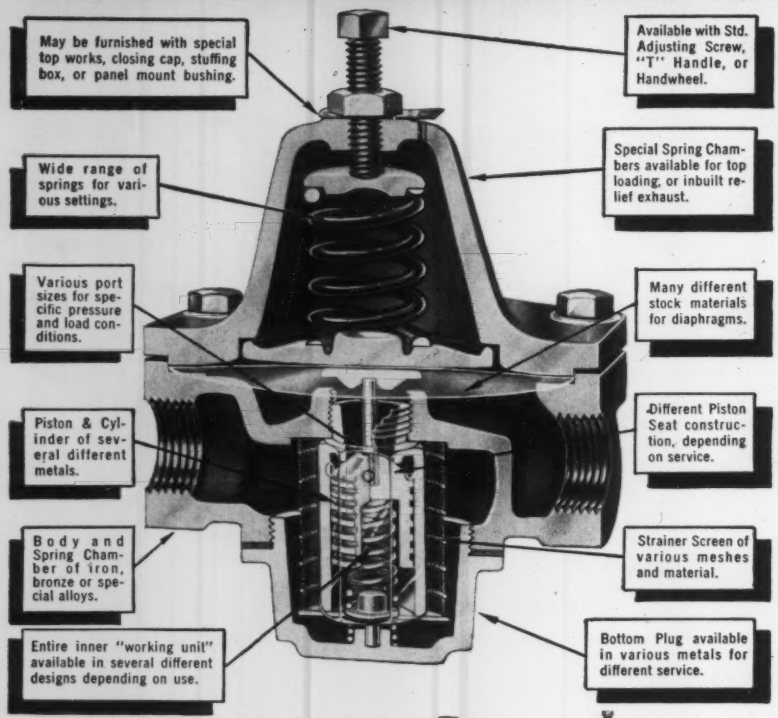
When strategic aircraft requirements indicated a NEW type of universal joint, MECHANICS engineers developed it. Design, metals, machining, tolerances, heat-treating, hardening, stamina, balance and lubrication — all were adapted to specific aircraft precision. Let MECHANICS engineers design and build universal joints that are equally well suited to the exact power transmission needs of *your* product. The competitive advantages that designed-for-the-job MECHANICS Roller Bearing UNIVERSAL JOINTS provide, are well worth investigating—while your new models still are on the drawing board.

MECHANICS UNIVERSAL JOINT DIVISION
Borg-Warner 2032 Harrison Ave., Rockford, Ill.

MECHANICS
Roller Bearing B-W
UNIVERSAL JOINTS

For Cars • Trucks • Tractors • Farm Implements • Road Machinery • Aircraft • Tanks • Busses and Industrial Equipment

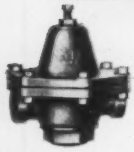
how *Cash-Acme* provides the *Correct Answer* to 1,017 reducing valve cost problems


May be furnished with special top works, closing cap, stuffing box, or panel mount bushing.
Available with Std. Adjusting Screw, "T" Handle, or Handwheel.
Wide range of springs for various settings.
Special Spring Chambers available for top loading, or inbuilt relief exhaust.
Various port sizes for specific pressure and load conditions.
Many different stock materials for diaphragms.
Piston & Cylinder of several different metals.
Different Piston Seat construction, depending on service.
Body and Spring Chamber of iron, bronze or special alloys.
Strainer Screen of various meshes and material.
Entire inner "working unit" available in several different designs depending on use.
Bottom Plug available in various metals for different service.

Here's How: With over 1,017 models and modifications of Cash-Acme's *standard* Type B Pressure Reducing Valve available and already in high production, the *right* regulator can usually be quickly selected from stock to do the job you require. This offers important cost savings as delays, special tooling and custom design and engineering are eliminated.

Do as other cost conscious engineers and purchasing men are doing and switch to CASH-ACME.

A fact-jammed eight-page bulletin, with honest and accurate capacity charts, is available free of charge. Write today.



Type "B"—Rugged Industrial Type Pressure Reducing Valve ... A truly *universal* piece of equipment. Standard models for:

- STEAM
- HOT WATER
- COLD WATER
- AIR
- LIGHT OIL
- NO. 6 OIL
- AMMONIA
- DIFFERENTIAL REGULATOR
- WITH INBUILT RELIEF
- AIR OR OIL TOP LOADING
- PANEL MOUNTING

FOR THE *Correct Answer*

CASH AUTOMATIC VALVES ACME

A. W. CASH VALVE MANUFACTURING CORP.

6613 E. Wabash Ave., Decatur, Illinois

New Parts

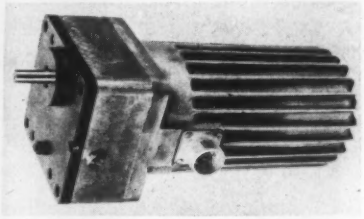
blies. It has high internal burst strength, and is for use where metal tubes or studs are to be inserted into tubular plastic insulators, such as in brush-holder assemblies and insulated bushings. Tubing is available in ID sizes from 0.093 to 0.379-in., in wall thicknesses from 0.010 to 0.0781-in., depending upon piping size, and in lengths to 25 in. It has a natural color, axial compression strength of 17,100 psi, density from 1.20 to 1.25 grams per cu cm, and water absorption gain of 5.10 to 5.65 per cent. Material meets NEMA specifications for grade XX rolled tubing. **National Vulcanized Fibre Co.,** 1057 Beech St., Wilmington 99, Del.

Circle 696 on page 19

Gearhead Motor

meets requirements of MIL-M-17059 and MIL-S-901

Oil-filled gearhead motor is a two-speed unit designed for 220 v ac, 60 cps, three-phase service. It is equipped with an electrically



energized brake which stops motor within 0.2 second. Motor is totally enclosed to provide protection against moisture, dust, fungus and salt spray, and meets requirements of MIL-M-17059 and MIL-S-901. Ambient temperature range is --65 to 200 C. **Western Gear Corp.,** P.O. Box 182, Lynwood, Calif.

Circle 697 on page 19

Axial Flow Fans

have Venturi ring mounts

Series of 4, 8 and 10-in. axial-flow fans have Venturi rings to facilitate direct mounting against enclosures, cabinet walls or dust-filter boxes without further rings and brackets. Fans are available for 50, 60 or 400-cycle operation,

Circle 493 on page 19

Vacuum-melted alloys stay stronger, more ductile at high temperatures

Where engine temperatures exceed 1200°F, for example, vacuum-melted alloys add high strength without loss of ductility. Reason? In vacuum-melting, metals of unprecedented composition control and purity are standard. Inclusions are almost totally absent; mechanical and physical properties are higher and more uniform in all directions, and also from heat to heat. Furthermore, many alloys are readily made under the precise control of vacuum melting that are otherwise impossible or uneconomical to make at all.

Vacuum Metals Corporation, Division of Crucible Steel Company of America, is the first and largest producer of vacuum-melted metals. It is now melting heats up to 3000 pounds. Large sections and a wide variety of alloys are available to the aircraft industry. We would like to work with you on metals problems which vacuum-melted alloys may solve. Please write, giving as much detail as possible, to *Vacuum Metals Corporation, Division of Crucible Steel Company of America, P. O. Box 977, Syracuse 1, N. Y.*

Vacuum-melting is adding new performance to these metals. Do you have an application that may benefit from their use?

- High temperature alloys
- Bearing steels
- Tool steels
- High strength alloy steels
- Low alloy steels for springs
- Stainless steels
- Hard facing alloys
- Electronic alloys
- Nuclear reactor materials
- Special nonferrous alloys
- Alloys for investment castings

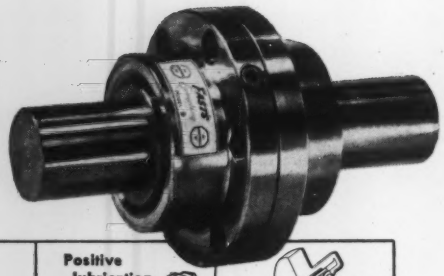
VMC®

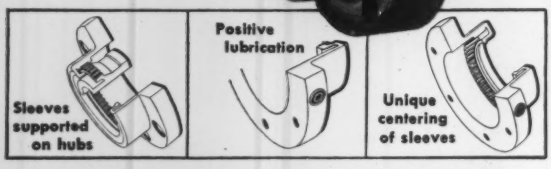
VACUUM METALS CORPORATION

Division of Crucible Steel Company of America

Circle 494 on page 19

FAST'S Model B Coupling





reduces downtime and upkeep for light-to-medium drives!

Now you can profit from the durability and economy of famous Fast's couplings in a smaller and lower-cost version—available in 3 sizes for shafts up to 2⅝" in diameter.

The Model B coupling gives you the same features that have made Fast's the world's leading coupling for over 35 years. You get the same trouble-free performance, longer service life and lower maintenance costs. You also get prompt delivery because stocks are on hand to meet practically every need. Free engineering service is also available.

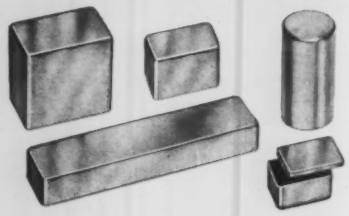
Write today for more details to KOPPERS COMPANY, INC., Fast's Coupling Dept., 3508 Scott Street, Baltimore 3, Maryland.

Engineered Products Sold with *Service*

KOPPERS

THE ORIGINAL *FAST'S Couplings*

Circle 495 on page 19



deep drawn aluminum boxes and cases

1400 STANDARD SIZES TO CHOOSE FROM

with no tooling cost!

Choose from more than 1400 standard sizes and save tooling cost. All can be trimmed and modified to your specification by secondary operations...brackets and fasteners installed, holes and louvers punched, welding, painting, etc. Choose from rectangular, round, square boxes and covers. Custom deep drawn parts at nominal cost using exclusive ZERO-method tooling—send your print or contact your local ZERO representative for a quotation.

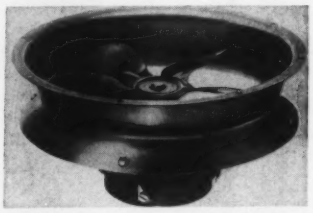
Write for complete new ZERO catalog

ZERO MANUFACTURING COMPANY

1121 CHESTNUT, BURBANK, CALIFORNIA

Circle 496 on page 19

New Parts



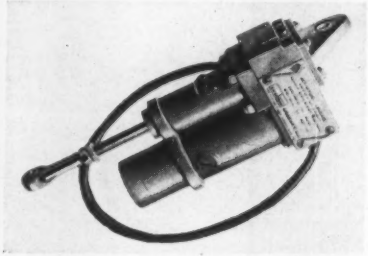
for variable power-supply frequencies, and for all voltages and phases. They are powered by 24-slot motors, and are supplied in models for various conditions of altitude or ambient temperatures. Fans and motors are matched for static-pressure conditions. **Ashland Electric Products Inc.**, 32-02 Queens Blvd., Long Island City 1, N. Y.

Circle 698 on page 19

Linear Actuator

operates by remote control

Originally designed for helicopter use, this actuator enables pilots to control tracking of rotor blades from cockpit during flight. Easily adaptable for industrial use, the unit handles loads to 150 lb at speed of 0.03 ips. Actuator meets MIL-E-5272 environmental and vibration requirements, and includes



externally adjustable limit switches, externally adjustable positive over-travel stops, and overload protective clutch. **Lyndon Aircraft Inc.**, 140-55 Clifford St., Newark, N. J.

Circle 699 on page 19

Miniature Clinch Nuts

flush mount in thin stock

Two miniature self-locking clinch nuts have shank design which permits flush installation in stock as thin as 0.030-in. Type NCFM

It's too hot in August
to read a long story . . .

BUT HERE'S A MAJOR POINT TO REMEMBER:

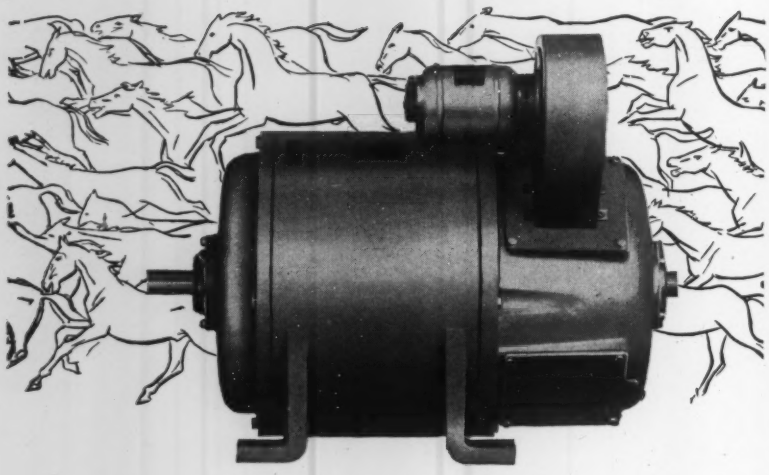
More than 125 Bellows Field Engineers, in every major industrial area in the United States and Canada, safeguard you against excessive "down time" — are at your call to service quickly air-operated equipment using Bellows "Controlled-Air-Power" Devices.

The Bellows Co.
Dept. MD-857
AKRON 9, OHIO

97CA

Circle 497 on page 19

SPECIAL



five equals fifty

This DC motor is actually ten times the motor it appears to be. It is the size of a 5-h.p. motor, but it's rated 50 h.p. short-duty, and over 20 h.p. continuous.

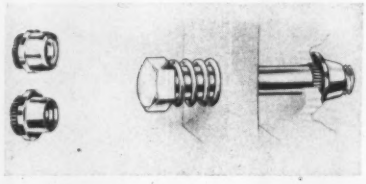
In designing this particular shunt-wound motor, high power in a small space was the major consideration, but not the only one. It also had to accelerate to 6000 r.p.m. within one second and withstand frequent, fast reversals without excessive overheating. Physically, this small-scale giant measures just 16" long by 9½" dia., and weighs only 115 lbs.

Admittedly, this is a special motor. It is also typical of ESCO's unusual ability to design and build all kinds of special rotary equipment to meet particular needs. For over forty years ESCO has been pleasing its customers by finding answers that exactly match special requirements. Perhaps our solution to your particular motor problem will please you, too.

Refer to Esco Catalog in section 4a/E1 in Sweet's Product Design File, or write direct for general catalog No. 56PD. Why not also send us details on your special problem — we'll be glad to show you how we would go about solving it for you.

ESCO ELECTRIC SPECIALTY CO.
179 South Street, Stamford, Conn.

nuts incorporate nylon locking inserts for temperatures to 350 F; Type LHCFM is an all-metal nut with elliptical crown-locking device for use to 555 F. Both types require two shank lengths for flush-mounting installation in material ranging in thickness from 0.030 to 0.060-in. and 0.060-in. and above. Eight thread sizes range from 2-26



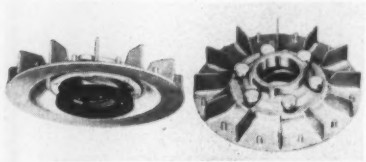
to ¼-28. Nuts are cadmium-plated steel, and meet applicable performance requirements of AN-N-5, AN-N-10 and/or MIL-N-25027 (ASG). **Elastic Stop Nut Corp. of America**, 2330 Vauxhall Rd., Union, N.J.

Circle 700 on page 19

Switch-Fan Unit

for single-phase motors

Syncro-Snap centrifugal switch has been incorporated into a die-cast cooling fan to provide a single unit which performs both cooling and starting winding cut-out functions required in single-phase motors. Unit is also suitable in any situation where cooling is required in



conjunction with speed detection. It is designated the Syncro-Fan switch, and is composed of only three parts. **Torq Engineered Products**, W. Monroe St., Bedford, O.

Circle 701 on page 19

Flexible Coupling

permits ¼-in. axial motion

Flexible coupling is for use in aircraft and missile field. Designed to meet requirements of military specification C-25014, the coupling, designated 6-6001, permits total of

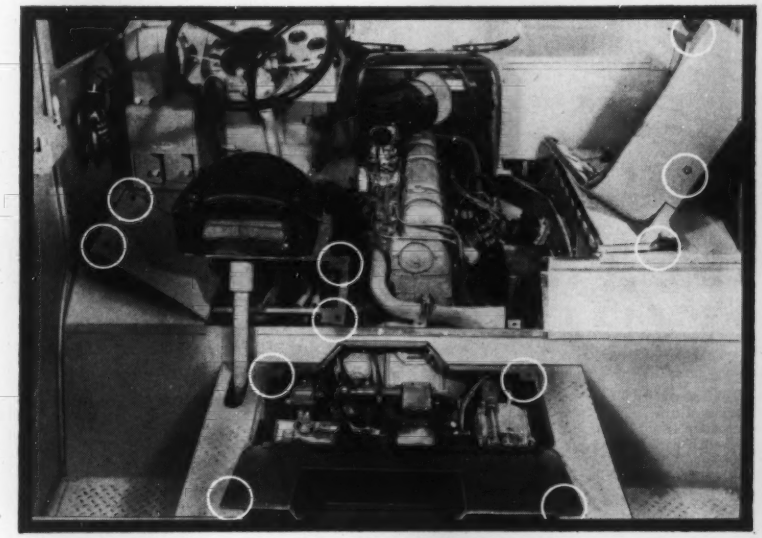
Circle 498 on page 19

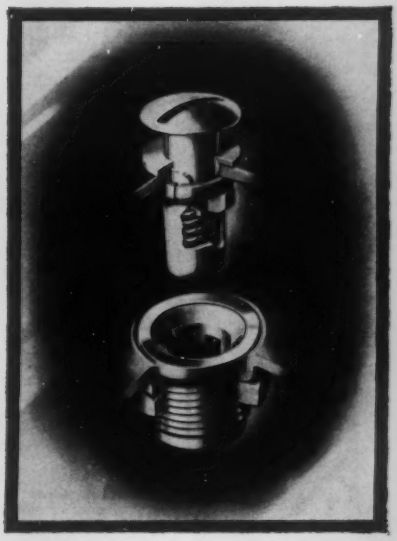
Design problem:

Fastening of removable panels

Your best answer:

Economical, easy-to-install QUICK-LOCK





Photograph courtesy Divco-Wayne Corporation, Detroit, Michigan

In Divco delivery trucks,

QUICK-LOCK guarantees

trouble-free opening and closing

of cowlings and access panels

Among the outstanding design features which have contributed to the success of Divco door-to-door delivery vehicles is the sure, quick closing and opening of cowlings and panels. To provide easy access to engine and transmission, Divco specifies Simmons QUICK-LOCK on demountable covers of various shapes and thicknesses.

QUICK-LOCK has unlimited applications in the electrical and electronic, automotive, appliance, aircraft, and other manufacturing fields. *Here's why* millions are in use today on many types of valuable equipment cases, weather-tight lighting units, voltage regulators, engine panels, and access panels and doors:

- A 90-deg. turn locks and unlocks QUICK-LOCK. No special tools needed.
- Stud is self-aligning; speeds up mounting and demounting of removable panels.
- When unlocked, stud is self-ejecting—easily checked by visual inspection.
- Various stud and receptacle types... oval, flush, and wing-head studs; easily installed plate and screw-type receptacles.
- Helical spring in stud supports initial load; solid stud part holds increased load.
- Design features allow for curved sheet installation, and even slight misalignment of holes.
- *Maximum economy in production* assured by single hole mounting of screw-type receptacle.

Send today for the Simmons Catalog

Where does QUICK-LOCK belong in your design? For complete information and specifications, write for the Simmons Catalog today. Samples and free engineering service are available upon request.

SIMMONS

FASTENER CORPORATION

1756 North Broadway, Albany 1, New York

QUICK-LOCK • SPRING-LOCK • ROTO-LOCK • LINK-LOCK • DUAL-LOCK

Circle 499 on page 19

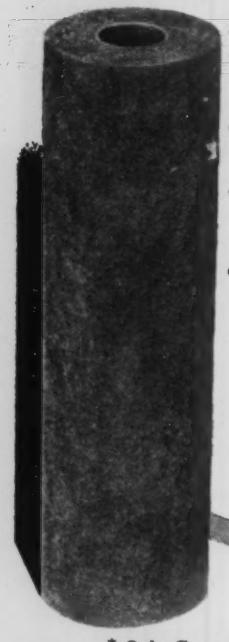
FILTRATION *Engineered** TO MEET METAL WORKING NEEDS

CUNO

A Complete Line Including

MICRO-KLEAN

FIBER CARTRIDGE FILTERS



- **FOR COOLANT LIQUID SYSTEMS** . . . remove chips and grinding swarf from stream . . . insuring far finer finishes on surface and centerless grinding and machining operations.
- **FOR HYDRAULIC SYSTEMS** . . . remove solid particles that may damage equipment or cause malfunction.
- **FOR LUBE OILS** . . . insures protection against chips, swarf and other harmful particles accidentally introduced into system.
- **FOR PAINTING, FINISHING** . . . filter paint and air lines. Improve product appearance, protect against delays from clogged nozzles.

Two cartridge types – White Cellulose and Wool – provide filtration from 5 to 75 microns. Exclusive Cuno "Graded Density" feature *doubles* cartridge life . . . cuts replacement costs *in half!* A complete line of standard Cuno Housings is available for every application requirement.

* Only Cuno offers you a truly complete line that includes *several* distinct types of filter media. Cuno also offers a complete application engineering service through the Cuno Field Engineer conveniently located in your area. He is qualified to help you select the right filter type and model to solve your problems.

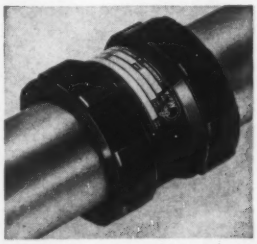
WRITE NOW FOR FULLY DESCRIPTIVE PRODUCT LITERATURE . . . *Free Micro-Klean Bulletins will be sent to you by return mail.*

CUNO ENGINEERING CORPORATION
1408 SOUTH VINE STREET, MERIDEN, CONN.
TELEPHONE: BEverly 7-5541

EDGE-TYPE, WIRE-WOUND, SCREEN, FIBER CARTRIDGE and POROUS METAL FILTERS

Filtration Engineers in Principal Cities

New Parts



¼-in. axial motion. Standard beaded tube ends and O-rings are used to provide sealed fitting attachment. Standard gland dimensions allow space for seal swell and permit easier axial motion of tubes. Temperature limitations are established by compound used for seals; pressure limitations are set by tubing wall and bead stiffness. Fluids other than fuel can also be handled and couplings can be completely assembled by hand. **On Mark Couplings,** 200 North Avenue 64, Los Angeles 43, Calif.

Circle 702 on page 19

Beam Power Tube

for television and radio receivers

New 6DS5 beam power tube of 7-pin miniature type is for use as a Class A amplifier in audio-output stages of TV and radio receivers. Having high power sensitivity and high efficiency, tube in cathode-bias circuits delivers a maximum-signal power output of approximately 3.6 w with peak af grid-No. 1 voltage of 9.2 v. Cool op-

eration of grid No. 1 minimizes grid emission. Tube can be used with cathode bias and a relatively large value of grid-No. 1 circuit resistance. **Radio Corp. of America, Tube Div.,** Harrison, N.J.

Circle 703 on page 19

Air Cylinders

are throw-away type

Six single and double-acting throw-away stainless-steel air cylinders are available in 1, 2 and 3-in. strokes with 1 1/16-in. bore. All models contain vinyl U-cups

Progress Report:

SCHRADER AIR PRODUCTS PERFORM JOBS IN SEQUENCE—AUTOMATICALLY

• Don't send a boy to do a man's job

When you say that, smile, if you're talking about air. Air can do *more* than a man's job. It can perform complicated, time-consuming operations faster, more accurately, and much more economically than *any* man.

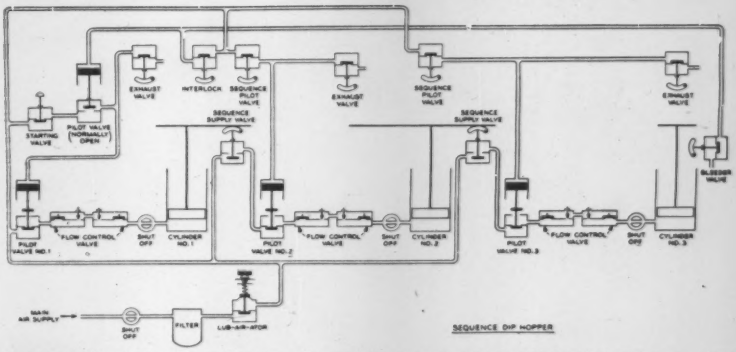
There was a time when air power was used for nothing but simple one-shot actions, but those days are far behind. Now, automation has brought air so far beyond the "bellows-in-the-forge" age that the contrast is startling.

Manufacturers who think of Schrader Air Products only for the so-called simple-minded jobs are missing out on one of the true revolutions of our times. Their competition is using air systems, on the other hand, to make precision operations to close tolerances, for operations in sequence, and you can't blame them if they're a little smug about the amazing effectiveness, economy, and safety they've developed.

FOR EXAMPLE:

• This job was driving sane men off their rockers

Until recently, the toughest job at a New Haven plating company was dipping baskets of plated parts in three successive baths. The triple bath sequence was not just monotonous — it was slow, expensive, in a corrosive atmosphere, and calculated to frazzle the tempers of workers. Then the operation was automated with Schrader Air Products. The dip hoppers now operate as if by magic—in solitary splendor. Completion of one sequence automatically starts another.



Schematic shows how a Schrader air system operates for plated part dippers, shortening the cycle, and releasing operators for more useful jobs.

The schematic on this page is eloquent. Combinations of Schrader cylinders, pilot valves, two way valves, and flow control valves have been engineered into a true automated sequence system. Once again, open-minded engineers discovered the best way—air—had definite advantages.

• What you don't know can hurt you

Most engineers already know that Schrader Air Products are available NOW, that the products are designed to be fitted together as simply as an Erector set, and that the hundreds of different parts available offer capabilities that are virtually limitless. Advantages? Well, here they are again: Exceptional economy is basic. Safety margins can be widened by the use of special control techniques. Simplicity of air systems allows fingertip-push-button-tiptoe operations that are fatigueless. Production is speeded up.

• Take a good look at yourself

Better yet, let *us* look you over. Schrader engineers will be happy to assist you in planning for the most efficient use of air in your plant. And they'll be glad to recommend products which most readily suit given applications . . . even packaged control sets that are so perfected that most press hazards are eliminated. Both hands must be used at once and can't get into mischief. Any machine using mechanical clutch, shears, brakes and friction clutches can use special controls. You may be very surprised at how painlessly Schrader can turn your idea into fact. Information is available by writing directly to us . . . and our distributors are conveniently located for fast delivery. Address A. Schrader's Son, Division of Scovill Mfg. Co., Inc., 476 Vanderbilt Avenue, Brooklyn 38, N. Y.

Schrader®
a division of SCOVILL

QUALITY AIR CONTROL PRODUCTS

A. SCHRADER'S SON • *Division of Scovill Mfg. Co., Inc.*
476 Vanderbilt Avenue, Brooklyn 38, N. Y.
Please send latest informative booklets which show Schrader's complete line of Air Control Products.

Name_____ Title_____

Company_____

Address_____

Circle 501 on page 19

ROCKFORD

MORLIFE® Spring Loaded CLUTCHES

Provide

100% MORE

TORQUE GRIP

Small Spring Loaded

Automotive Spring Loaded

Heavy Duty Spring Loaded

Oil or Dry Multiple Disc

Heavy Duty Over Center

Light Over Center

Power Take-Offs

Speed Reducers

ROCKFORD Spring-Loaded CLUTCHES, equipped with MORLIFE clutch plates, provide 100% more torque grip than previous type clutches of equal size. This permits the use of smaller diameter clutches. Easier operation is accomplished by reducing the required engaging pressure. 50% better heat disposal avoids down-time caused by burned or warped plates. Numerous field records prove that MORLIFE clutches operate 400% longer without plate replacement or adjustment. Let these NEW type clutches help improve the operation of *your* heavy-duty machines.

SEND FOR THIS HANDY BULLETIN

Shows typical installations of ROCKFORD CLUTCHES and POWER TAKE-OFFS. Contains diagrams of unique applications. Furnishes capacity tables, dimensions and complete specifications.

ROCKFORD Clutch Division BORG-WARNER

311 Catherine St., Rockford, Ill., U.S.A.

Export Sales Borg-Warner International — 36 So. Wabash, Chicago 3, Ill.

ENGINEERING B-W PRODUCTION

CLUTCHES

New Parts

mounted in aluminum-alloy piston. Cylinders can be used to damp, press, open and close jigs and fixtures, die set strippers, and for pilot operation of valves. **Bimba Hardware & Mfg. Co.**, 101 Main St., Monee, Ill.

Circle 704 on page 19

Stainless-Steel Sheet

withstands temperatures to 1500 F

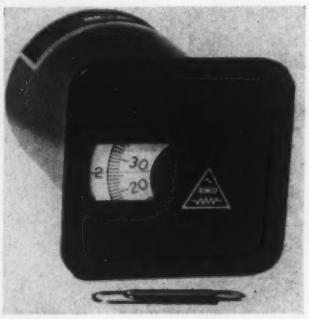
New stainless-steel sheet can be bent, drawn, swaged, formed, spun or welded without peeling or cracking. Process involves diffusion of chromium into surface of steel, where iron and chromium atom exchange takes place, forming stainless surface integral with base metal. Sheet is fully annealed, since high temperature is followed by slow cooling. Material withstands operating temperatures as high as 1500 F. **Chromalloy Corp.**, 450 Tarrytown Rd., White Plains, N. Y.

Circle 705 on page 19

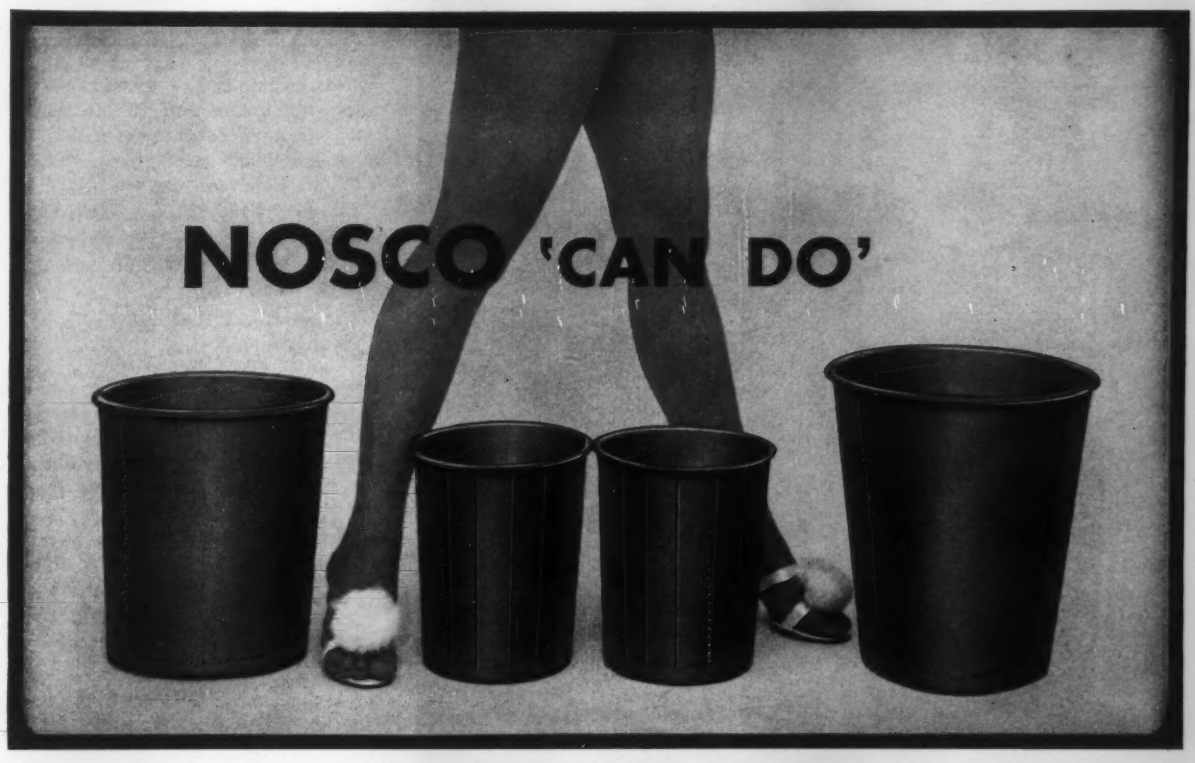
Vernier Potentiometer

has resolution of ten-turn unit

Rinco Type 49-A Verni-Pot provides single-knob control of two resistance decades. Two turns of the control knob cover the full range, and resolution is equal to a ten-turn potentiometer. Accuracy is ±5 per cent of full scale resistance; resolution is 0.1 per cent.



Circle 502 on page 19



Two at a time...

Wastebaskets molded for higher production... lower cost

A major manufacturer of metal housewares decided to broaden his line by adding plastic wastebaskets. His first step was to call in a Nosco sales-engineer . . . logical, because Nosco men are qualified plastic-parts technicians who know exactly how to put Nosco engineering and production facilities to work. The Nosco plant thus becomes the customer's own plastic molding department!

For the 8-quart basket, Nosco engineered *the deepest two-cavity mold ever built.* This hot-runner mold, which virtually eliminates all scrap, weighs more than a ton and is run in one of Nosco's large pre-plasticized presses.

The two larger size wastebaskets, pictured above, are now molded one at a time, but when production warrants, these parts can also be molded in two-cavity dies.

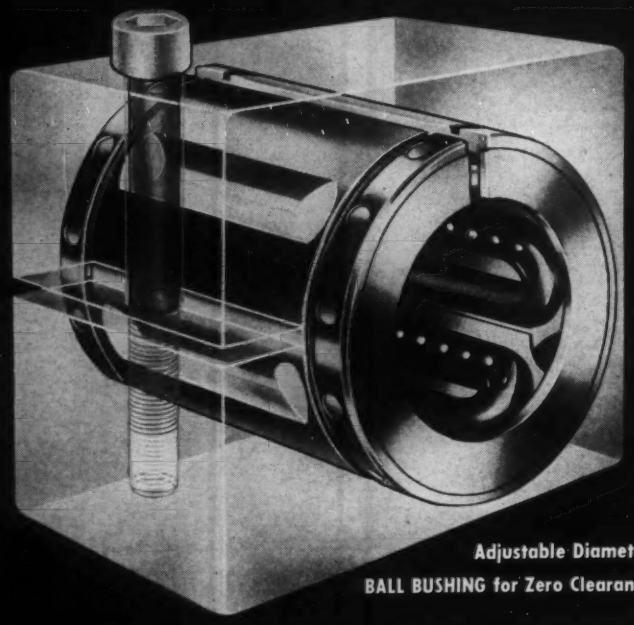
Nosco "Can Do" enabled this manufacturer to successfully produce deep-drawn parts at lower cost. Why not let one of our sales engineers put Nosco "Can Do" to work in designing your next plastic part? Please write.

NOSCO plastics, inc. • erie 2, pa.

World's largest injection molding plant

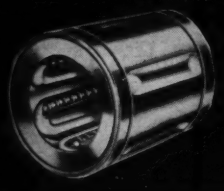
For other case histories—and for a glimpse of the Nosco plant and facilities, send for the free 12-page brochure, "How the Nosco Plant Works to Produce Your Needs in Practical Plastics."

NOW! Adjustable Diameter and Open
THOMSON
BALL BUSHINGS

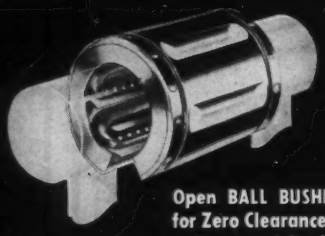


Adjustable Diameter
BALL BUSHING for Zero Clearance

The BALL Bearing for *all* your LINEAR MOTIONS



Precision Series "A" and
Low Cost Series "B" BALL BUSHING.



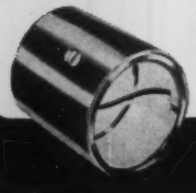
Open BALL BUSHING
for Zero Clearance on
Supported Shafts

Sliding linear motions are nearly always troublesome. Thousands of progressive engineers and designers have solved this problem by application of BALL BUSHINGS on *guide rods, reciprocating shafts, push-pull actions,* or for support of *any mechanism that is moved or shifted in a straight line.*

Improve your product! Up-date your design and performance with Thomson BALL BUSHINGS!

LOW FRICTION • ZERO SHAKE OR PLAY
ELIMINATE BINDING AND CHATTER
SOLVE SLIDING LUBRICATION PROBLEMS
LONG LIFE • LASTING ALIGNMENT

The various types cover a shaft diameter range of ¼" to 4". Small sizes available in Stainless Steel. Write for literature and name of our representative in your city.



THOMSON INDUSTRIES, Inc.
Dept. E, MANHASSET, NEW YORK

Also manufacturers of NYLINED Bearings
. . . Sleeve Bearings of DuPont NYLON

New Parts

Power rating is 4 w when used as a potentiometer and 20 ma when used as a rheostat. Operation is over frequency range from dc to 10 kc. **Research Instrument Co.,** P. O. Box 9168, Portland 16, Ore.

Circle 706 on page 19

Speed Reducers

mount directly on shaft of driven machine

Two shaft-mounted, worm-gear speed reducers include a torque-arm type and a flange-mounted type (shown). Both are available in three sizes with ratios from 7½:1 to 77:1, horsepowers from 0.63 to 8.82, and maximum output torque from 816 to 7678 lb-in. Units mount directly on shaft of

driven machine, eliminating use of couplings and bed plates. Slow-speed shaft of both series is provided with two external slots for removal of reducer from driven machine using standard wheel puller. **Winsmith Inc.,** Springville (Erie County), N.Y.

Circle 707 on page 19

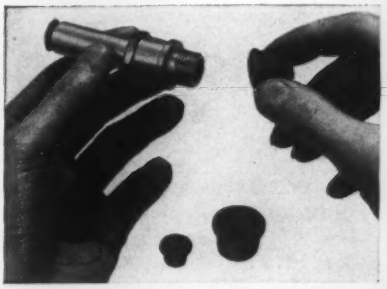
Elbow Fittings

simplify hose installation

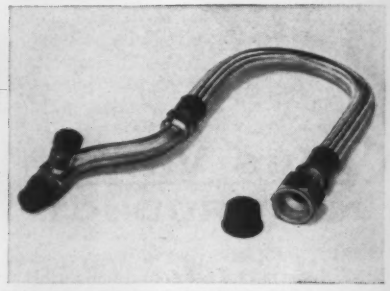
Hose elbow fittings simplify hose installation in confined spaces and reduce number of joints and fittings required. Fittings provide low flow restriction and are reusable. They are fabricated from formed tubing and are available in swivel-nut ends with JIC and SAE threads. Mating adapters are also supplied for straight gasket seal and pipe threads. Units are available in 45 and 90-deg configurations, and are for use with medium and high-pressure hose. Both short and extended length elbows are available. Applications in-

a free CaPlug assortment like this

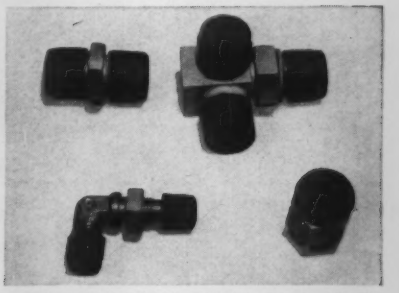
will give you dozens of ideas for protecting products like these



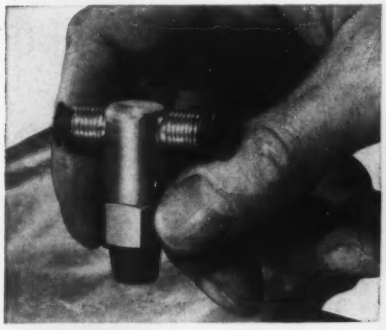
JUST PUSH THEM IN . . . OR PUSH THEM ON
Tapered (non-threaded) CaPlugs can be used as caps or plugs, inside or outside of threaded or plain fittings. Threaded styles are knurled to screw on or off with ease. Made of tough, flexible Polyethylene, CaPlugs are unaffected by most chemicals, acids and solvents . . . will not collapse, chip, break or shred.



"KID GLOVE" PROTECTION WITH A DUAL PURPOSE
Here's how Resistoflex Corp. makes two-fold use of CaPlugs "to protect critical threads and machined surfaces and to keep the interiors of hose assemblies clean and dust-free." Says Resistoflex, "CaPlugs prove most effective for both functions as well as being particularly easy to install."



COUNTLESS USES BY THOUSANDS OF USERS
Bell Aircraft Corp. applies both threaded and non-threaded CaPlugs to a wide variety of parts (such as these) in the manufacture of guided missiles, electronic components, rocket engines and servomechanisms. Throughout industry, many a company has found that CaPlugs provide the perfect answer to practically every closure need.



MAKES A PRODUCT LOOK ITS "SUNDAY BEST"
On this Alemite Accumatic Valve, colorful red CaPlugs add snappy eye appeal and indicate care of manufacture. Says Stewart-Warner Corp., "CaPlugs help impress the customer with the steps that have been taken to protect the equipment and convince him of the continuing need for protecting lubricants against contamination."

THERE'S A CAPLUG THAT WILL DO THE TRICK *You name it! With numerous styles (threaded and non-threaded) stocked in over 500 sizes, "off-the-shelf" deliveries can be made from a 35,000,000 inventory to answer your immediate requirements promptly. You get closures that are right for your jobs . . . right on time.*

GET A FREE BOX OF CAPLUGS, DETAILS AND PRICES BY MAILING THIS COUPON

CAPLUGS DIVISION, PROTECTIVE CLOSURES CO., INC.
2201 Elmwood Ave., Buffalo 23, N. Y.

RUSH a free assortment of CaPlugs, literature and prices to us, without obligation.

NAME _____ TITLE _____

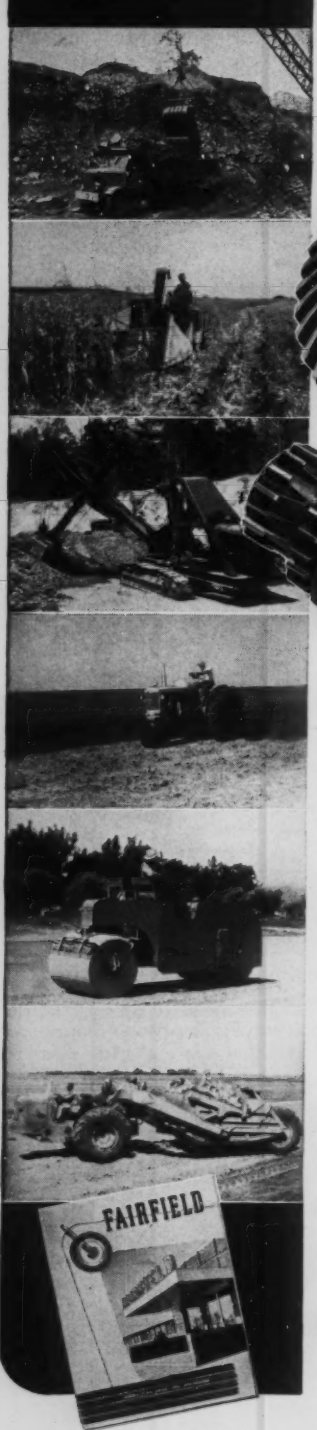
FIRM _____

ADDRESS _____

CITY _____ ZONE _____ STATE _____

Circle 505 on page 19

GEARS by FAIRFIELD



A Plus Value IN ANY PRODUCT!

If GEARS are a vital part of the product you make, there is no finer recommendation for the QUALITY of your product than to be able to say it is equipped with "FAIRFIELD GEARS."

Long producers of the gears needed in high grade trucks and tractors, Fairfield now brings the same standards for GEAR PERFORMANCE to a wide variety of products: Agricultural Implements . . . Power Shovels . . . Machine Tools . . . Diesel Locomotives . . . Road Graders . . . Lift Trucks . . . Road Rollers . . . Pump Drives . . . Winches . . . Military Vehicles . . . and a host of others.

Fairfield's facilities are unexcelled. Here "under one roof" in a new and ultra modern plant, Fairfield has everything needed for producing all kinds of gears: spur . . . herringbone . . . spiral bevel . . . ground tooth spiral bevel . . . straight bevel . . . coniflex bevel . . . hypoid . . . zerol . . . worms and worm gears . . . splined shafts . . . differentials. Get acquainted with Fairfield — your inquiry will receive prompt attention.

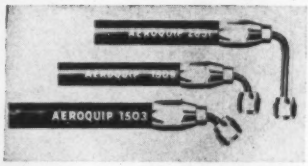
FAIRFIELD
MANUFACTURING CO.

2307 S. Concord Rd.,
Lafayette, Indiana

For FINE GEARS

Send for illustrated bulletin describing Fairfield's facilities.

New Parts



clude any hydraulic, fuel, air, water or lubricating oil installation requiring short-radius connection. **Aeroquip Corp.,** Jackson, Mich.

Circle 708 on page 19

Pushbutton Switches

are miniature units

Button Switch is a small, completely enclosed unit with metal housing. It is available with red or black pushbuttons, nonlocking, for behind-panel mounting or mounting from front. Available in

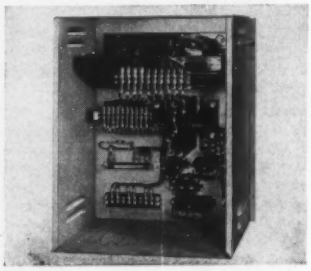
two contact arrangements, unit is rated at 250 ma noninductive load, ac, 30 w maximum. Tine-Switch has springs insulated and interlocked by notched phenolic washers. One-piece plastic shaft eliminates need to remove button when inserting switch through mounting panel. Integral contacts are suitable for low-level circuits where low resistance is not a factor. **Switchcraft Inc.,** 1328 N. Halsted St., Chicago 22, Ill.

Circle 709 on page 19

Magnetic Amplifiers

control heater temperature

Packaged magnetic amplifier Powerlink units provide close control



Circle 506 on page 19

Flexon®

bellows and bellows assemblies

design and application briefs

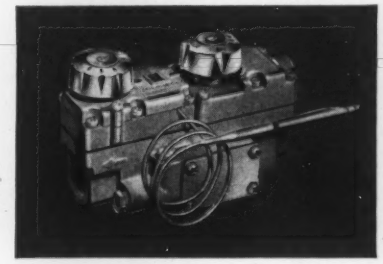
How Honeywell Uses Bellows for Positive Temperature Control with Their Adatrol* Gas Valve

HONEYWELL

The V5153 Adatrol* Thermostatic Gas Valve, manufactured by Minneapolis-Honeywell Regulator Company is a 100% shut-off gas cock and a bellows-actuated snap-acting thermostat for gas heating devices.

How it Works

When the pilot flame is normal, the thermo-electric power generated by an appropriate pilot burner-thermocouple combination energizes an



Adatrol* Thermostatic Gas Valve.

electro-magnet in the Pilotstat to hold the Pilotstat valve open. However, should the pilot flame become inadequate for proper ignition of the main burner, the thermo-electric current quickly drops off causing the valve to close and block gas flow to the pilot and main burner.

Flexon Bellows is the Heart of the Control

Automatic temperature control is provided by the snap-acting thermostat section that incorporates a Flexon Bellows Assembly. The temperature sensing element (a bulb) is connected to the internal actuating element (a bellows) by a capillary tube. The bulb-tubing-bellows combination is completely filled with a hydraulic temperature sensitive liquid. Changing temperature in the area surrounding the bulb creates a changing pressure in the bellows, which actuates the valve.

Due to the small percentage of total fill in the bellows and capillary, the control is not appreciably affected by temperatures other than at the bulb location. Because it is a solid fill, instrument calibration is unaffected by altitude changes.

Why Flexon Bellows Are Used

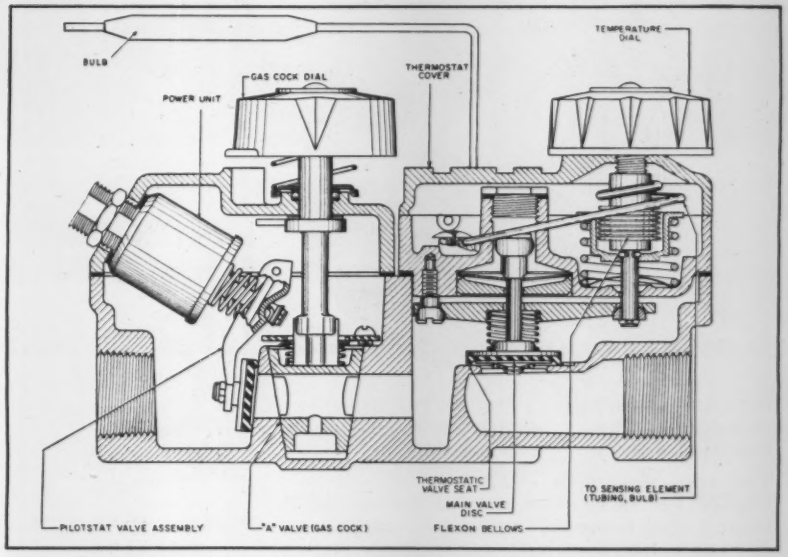
Minneapolis-Honeywell uses Flexon Bellows Assemblies in the Adatrol* Valve to take advantage of Flexonics Corporation's facilities and bellows manufacturing know-how. Flexonics' application engineers are cost conscious, skilled in recommending the bellows or bellows assemblies that provide the performance required by the device at the lowest price consistent with these requirements.

*Adatrol is the trademark of Minneapolis-Honeywell Regulator Co.

View in Flexonics laboratories showing mass spectrometer being used to test bellows for leakage.

Engineering Assistance

The Flexonics Application Engineering Staff will be pleased to assist you in your bellows application problems. For specific recommendations send an outline of your requirements. For your bellows reference file, write for the Flexon Bellows Design Guide.



Cross section of the Adatrol* unit showing the arrangement of elements.

Flexonics Corporation
BELLOWS DIVISION

1339 S. Third Avenue, Maywood, Illinois

In Canada: Flexonics Corporation of Canada, Limited, Brampton, Ontario

Also Manufacturers of Rubber and Metal Hose Assemblies • Expansion Joints • Aircraft Components

NEW...from WINSMITH SPEED REDUCERS

SHAFT MOUNTED WORM GEAR SPEED REDUCERS

SERIES "ST"
Torque Arm Type

SERIES "SF"
Flange Mounted Type

Now you can specify Winsmith performance, dependability and economy for applications requiring a shaft mounted speed reducer.

The new Winsmith "ST" and "SF" series require less space than conventional models because they eliminate the need for couplings and bed plates. Both series are currently available in three sizes . . . in ratios from 7½:1 to 77:1 . . . horsepower from .63 to 8.82 . . . maximum output torque range from 816 to 7678 in. lbs.

These new shaft mounted models also embody all the advanced engineering and construction features that make Winsmith Speed Reducers first choice for any application from 1/100 to 85 h.p.

WRITE . . . FOR NEW CATALOG

For all the facts and complete technical data on Winsmith Shaft Mounted, Worm Gear Speed Reducers, write today—on your company letterhead, please—for Catalog No. SM-57.

WINSMITH, INC. 16 Elton Street, Springville, (Erie County), N. Y.

New Parts

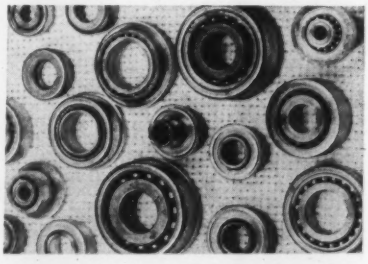
of heater temperature in electric furnaces and have other applications where kilowatts of power must be controlled by milliwatt signals. Units are available from 0.5 to 10.0 kw, with input resistance of 2000 to 20,000 ohms, and input ranges of 0-5, 0-15, 4-8 and 0-20 ma. Units are completely wired for installation in existing control systems. **Vickers Inc.**, Vickers Electric Div., 1815 Locust St., St. Louis 3, Mo.

Circle 710 on page 19

Ball Bearings

are semiprecision, low-speed units

Omega ball bearings provide wide range of antifriction units for shafts ⅛ through 1 in. in diameter. The semiprecision, low speed units



include radial and thrust bearings (flanged and unflanged), single and double-race rollers, prelubricated units, and dust-sealed assemblies. **Freeway Washer & Stamping Co.**, P.O. Box 1756, Cleveland 5, O.

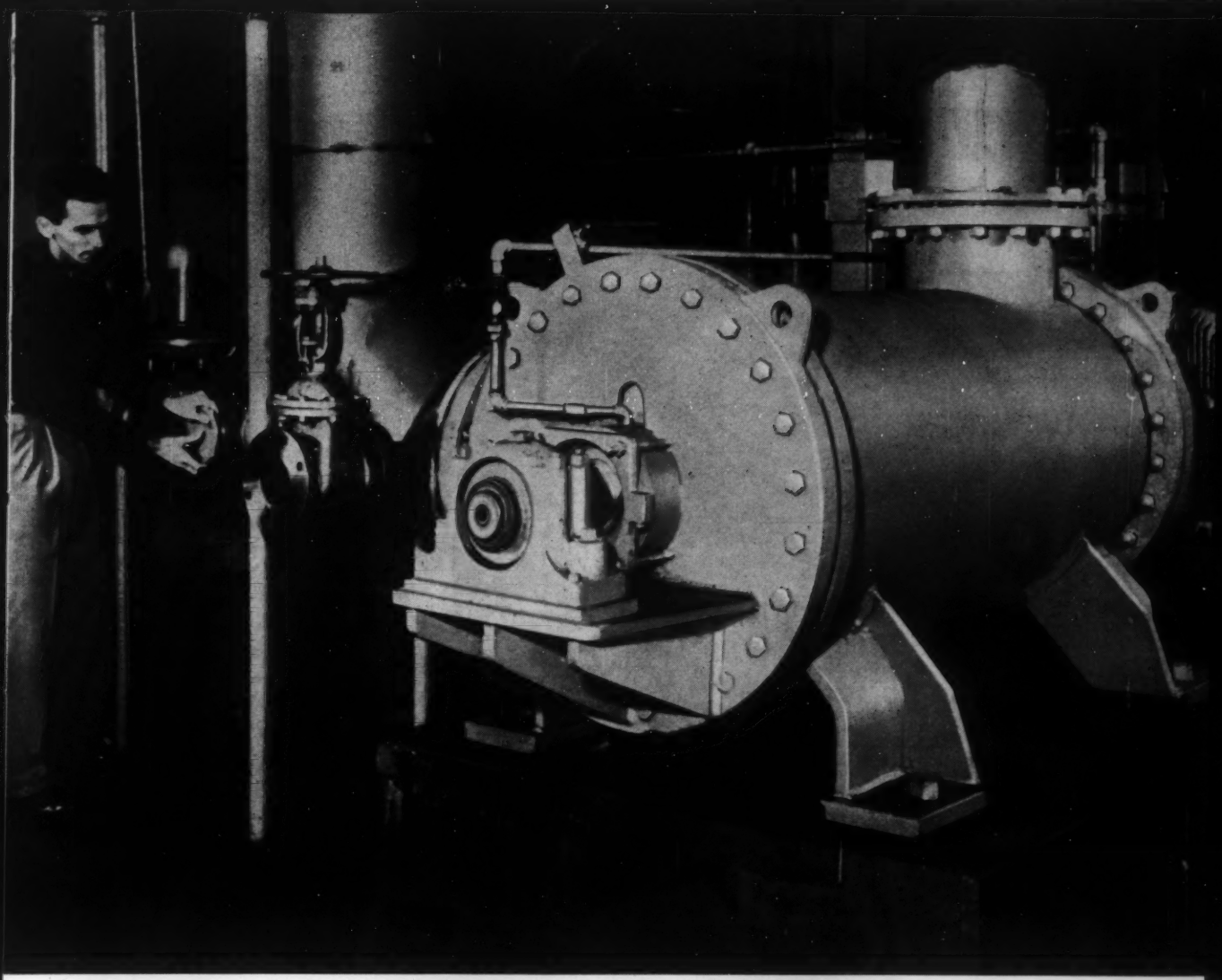
Circle 711 on page 19

Shaft-Angle Converter

provides high-speed computing accuracy

Lightweight shaft-angle converter provides high-speed computing accuracy and recording ease. It converts rotary motion into a coded system of numbers for use in airborne, military and industrial applications. Unit provides a binary decimal read-out of 1 in 3600 counts at 40 codes per revolution of input shaft. Intermittent gearing and precision bearings provide low driving torque. Input shaft rotates at speeds to 300 rpm in either direction. Drive system translates each code read-out within least significant figure.

Circle 508 on page 19



Chlorine dioxide mixer in service at the Carolina Division of Riegel Paper Corp. The unit was manufactured by Improved Machinery Inc. It is lined with ⅛" Rem-Cru A-70 titanium sheet.

Titanium liner gives low-cost protection to a conventional metal

Even a small amount of titanium can protect an entire unit from corrosion damage. Here's an example...

Highly corrosive chlorine dioxide would quickly ruin the conventional material in the mixer shown above. So, titanium, virtually immune to such attack, was used to form a protective liner. Sheets of ⅛" thick Rem-Cru titanium were welded together and formed into a cylinder, which was "rolled in" to fit the mixer shell tightly. A full year's trouble-free service again shows titanium to be the least expensive metal in terms of service life.

Titanium has many other advantages. It's as strong as steel, for example, yet 44% lighter. And it's a practical way to extend service life by as much as 10, 20, even 50 times. Why not let a qualified Rem-Cru engineer help you work out specific applications.

REM-CRU TITANIUM — *World's Most Versatile Metal*

Write Dept. MD-8 for the Rem-Cru Review—a free periodical presenting the latest data on titanium.

MIDLAND, PENNSYLVANIA

Sales Offices: 6033 East Bandini Boulevard, Los Angeles 22, California • 4501 W. Cortland Street, Chicago 39, Illinois • 405 Lexington Avenue, New York 17, N. Y.

Circle 509 on page 19

WALKER-TURNER
FLEXIBLE SHAFT DIVISION

PROUDLY JOINS

Robertshaw-Fulton
CONTROLS COMPANY

Custom designed flexible shafting for:

AIRCRAFT APPLICATIONS
APPLIANCES
INDUSTRIAL MACHINES
RADIO AND ELECTRONICS
SPECIAL APPLICATIONS

Our new association with the Robertshaw-Fulton Controls Company offers many important advantages to users of high quality flexible shafting. Among them are greater field engineering representation, better service, a pooling of engineering and development talent and experience, and added prestige when you design Robertshaw-Fulton Flexible Shafting into your instruments and equipment.

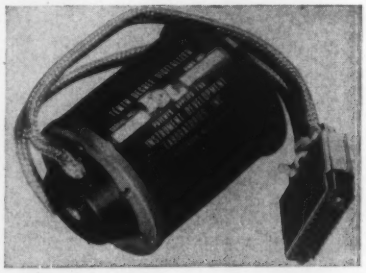
We welcome your inquiries. Our engineers will work with you on new or known applications. Outline your design problem in a letter today . . . at no obligation.

Mr. Controls®

Robertshaw-Fulton
CONTROLS COMPANY

FLEXIBLE SHAFT DIVISION • 110 Summit Ave., Chatham, N.J.

New Parts



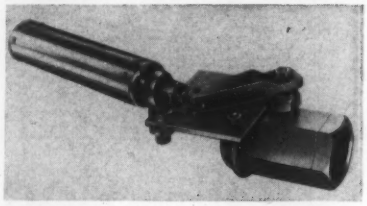
Unit withstands environmental conditions of applicable military specifications. **Instrument Development Laboratories Inc.,** 67 Mechanic St., Attleboro, Mass.

Circle 712 on page 19

Remote Operators

for ¼ to 4-in. ball valves

Air or hydraulic operators for ¼ to 4-in. ball valves are designed for two-way pneumatic or hydraulic remote and sequence operation. Operators permit manual operation of valves in case of power failure. They can be used with standard stainless-steel, carbon-steel, bronze, aluminum or polyvinyl chloride ball valves from high vacuum to pressures to 2000 psi. Speeds, which range from ½ second for ¼-in. valve to ¾ second



for 1¼ to 4-in. valves, can be increased or decreased. **Jamesbury Corp.,** 45 New St., Worcester, Mass.

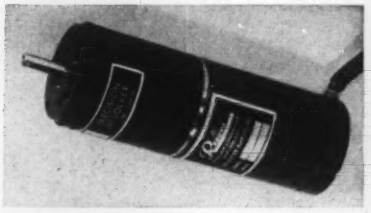
Circle 713 on page 19

Resolver-Booster Amplifier

eliminates external booster amplifier

Self-contained resolver - booster amplifier incorporates a standard size 15 resolver with functional accuracy of 0.1 per cent. Behind it are two small transistorized amplifiers which provide high input impedance, standardization and temperature and frequency compensa-

tion. They are of plug-in construction and can be replaced separately without removing unit from system. There is less than ±0.05 per cent temperature variation for the entire temperature range of −55 to 80 C. High input impedance eliminates loading effects. Unit measures 1½ in. diam



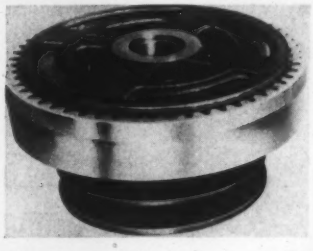
by 4 in. long. **Reeves Instrument Corp.**, 207 E. 91st St., New York 28, N.Y.

Circle 714 on page 19

Automatic Clutch

has built-in ventilating system

Series 800 automatic clutch has rapid heat dissipation provided by a built-in ventilating system, making it especially suitable for loads requiring extended acceleration periods. Clutch also has a 40-sq in. friction area. It is for use on both electric motors (2 to 5 hp at 1750 rpm) and gasoline engines (6 to 9 hp). It accommodates a variety of detachable sheaves for many



applications. **Salsbury Corp.**, Power Transmission Div., 1161 E. Florence Ave., Los Angeles 1, Calif.

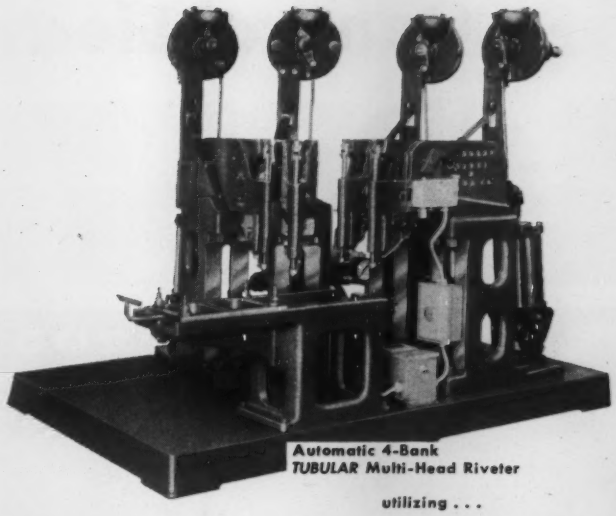
Circle 715 on page 19

High-Strength Studs

in ½ to 6-in. diam sizes

High-strength, custom-engineered studs for power-plant steam turbines, nuclear-reactor equipment and other high-temperature, high-pressure fastening jobs range in

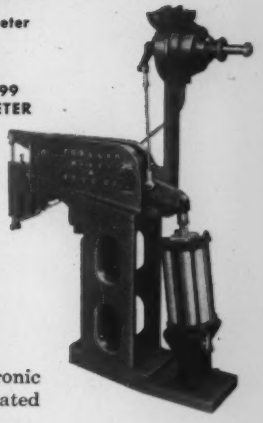
(*Continued on Page* 186)



Automatic 4-Bank *TUBULAR* Multi-Head Riveter

utilizing . . .

Basic Model 99 *TUBULAR* RIVETER



fastening automation...

"the *Tubular* way"

Volume production of furniture, auto parts, electronic assemblies, appliances, toys, etc. can be fully automated — when you fasten "the *Tubular* Way."

Tubular's Basic Model 99 Riveter can be ganged up in banks of 3 or *more* machines. With its modular design, a mass production ***Tubular*** Multi-Head Setting Machine can be engineered for your own volume assembly. You can then fasten *several rivets* — of *different types* — in *several planes* — in *different locations* — all in *one operation*. Assembly *savings* as high as 50-75% can be made.

Here are the *savings* and *advantages* gained by one manufacturer with his ***Tubular*** Multi-Head Riveter:

- 1 ***Tubular*** Multi-Head Riveter in two banks of 5 and 6 each replaced 8 conventional machines.
- Operators required reduced from 8 to 2.
- Automatic rivet settings increased from 8 to 11, with only 2 operators.

- Production increased 60%, from 250 to 400 units.
- Rearrangement of Basic Machines is easily accomplished, protecting original investment.
- Work-holding fixtures, adjustments in anvil elevations, etc. can be engineered for special applications.

To see how you can reduce costs and increase assembly production, call the nearest ***Tubular*** Rivet Engineer — or send blueprints direct to us. With ***Tubular's*** Multi-Head Riveting Machines, mass production possibilities are unlimited.

Tubular Rivet & STUD COMPANY
WOLLASTON (QUINCY) 70, MASS.

FASTEN AUTOMATICALLY BETTER and FASTER with TUBULAR'S RIVETS and MACHINES

MIDWEST OFFICE & WAREHOUSE — CHICAGO

BRANCH OFFICES: BUFFALO • CHARLOTTE • DALLAS • DETROIT • INDIANAPOLIS LOS ANGELES • NASHVILLE • NEW YORK CITY • PHILADELPHIA • ST. LOUIS SAN FRANCISCO • SEATTLE

See your local classified directory for phone numbers

Circle 511 on page 19

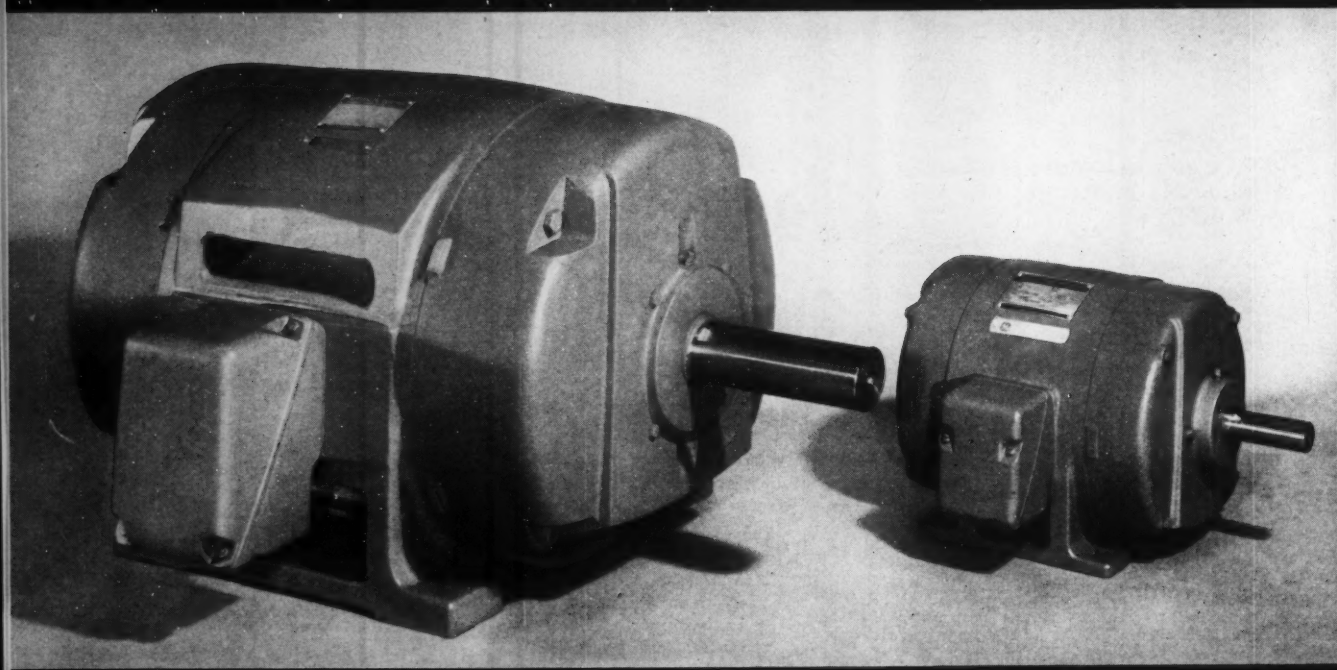
immediate shipment . . . all ratings

General Electric TRI-CLAD

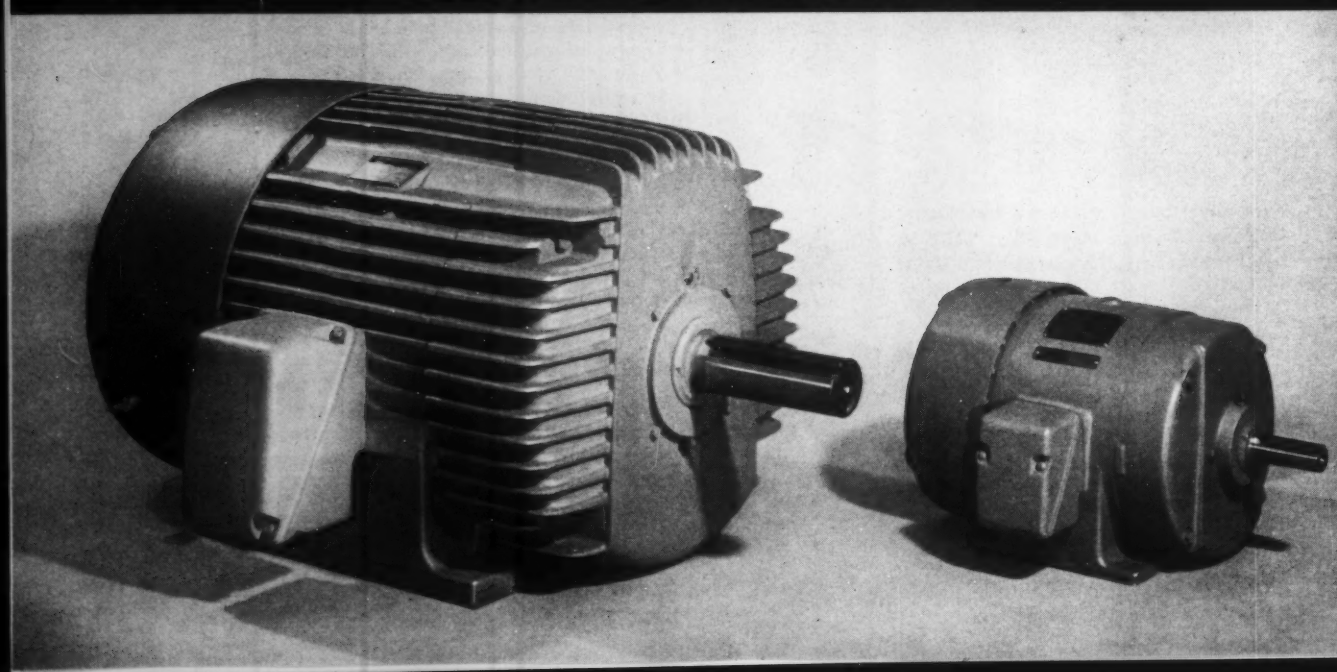
REG. U.S. PAT. OFF.

NOW UP

DRIPPROOF



TOTALLY ENCLOSED

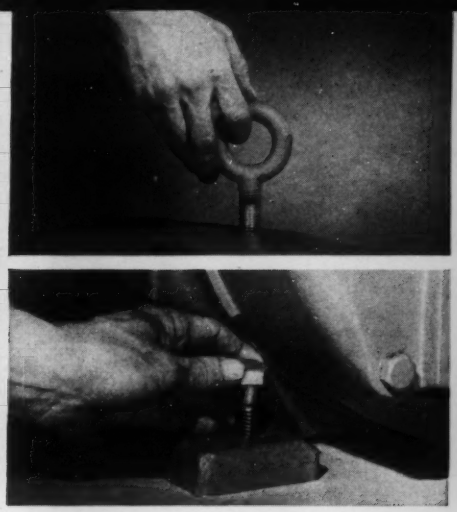


Motors in New NEMA Ratings

TO 125 HP

YEARS AHEAD BENEFITS

DESIGNED TO CUT COSTS—Up to 32% lighter and 50% smaller, new NEMA rated Tri-Clad '55' motors offer big savings on shipping, handling and storage costs. These more powerful, more compact motors permit big space savings on many machine designs.



DESIGNED FOR EASY HANDLING—Sturdy, forged eye bolts are supplied with new Tri-Clad '55' motors in larger ratings to permit easier motor handling. Provision for plenty of "wrench room" between motor feet and end shields cuts Tri-Clad '55' motor mounting time.

DESIGNED FOR EASY INSTALLATION—Perma-numbered leads simplify wiring and speed motor hook-up. Numbers are stamped on terminals and printed on every half inch of the Geoprene® lead covering. Leads are always identifiable even when taped or clipped.

FOR COMPLETE INFORMATION

FOR COMPLETE DETAILS on the new line of Tri-Clad '55' motors up to 125 hp, contact your local G-E motor distributor or the sales engineer at your nearby General Electric Apparatus Sales Office. You will get expert assistance in selecting and applying the right motor for your particular application.

FOR FREE SLIDE RULE—which lets you determine at a glance the weight and space-saving benefits of recently announced NEMA standards for larger motors—and for informative, free General Electric Tri-Clad '55' motor bulletin, please send attached coupon.

Section 891-6A
GENERAL ELECTRIC COMPANY
Schenectady 5, New York

Please send me the following publications:

☐ **FREE BULLETIN (GEA-6602) describing the many advanced features of new Tri-Clad '55' motors up to 125 hp.**

☐ **FREE SLIDE RULE (GEN-148) to determine weight and space-saving benefits of new Tri-Clad '55' motors.**

NAME _____

TITLE _____

COMPANY _____

ADDRESS _____

CITY & STATE _____

Progress Is Our Most Important Product

GENERAL ELECTRIC

Circle 512 on page 19

HOW CHACE THERMOSTATIC BIMETAL ACTUATES THE

The Therm-O-Disc Type E Series Thermostat is designed for compact installations in clothes dryers, room and unit heaters, central heating furnaces, air conditioning and ventilating equipment, aircraft and miscellaneous devices, for controlling temperatures up to 350°. Both the EA and EC Series are for single pole, single throw operations and can be supplied with normally closed or normally open contacts. The EA (shown) is best suited for controlling temperatures in air streams; the EC is intended for surface mounting. Both types are actuated by an exposed disc of Chace Thermostatic Bimetal, altho EA is also available with enclosed disc for protection against dust, lint, moisture, etc.

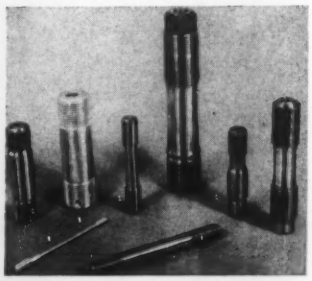
Here's how Therm-O-Disc works; The pre-calibrated disc of Chace Thermostatic Bimetal snaps from a normally concave to convex form at the pre-set point of temperature rise, in the manner of an "oil can". The impact of this positive snap action against a bumper causes instantaneous make or break of the contacts or circuit. Upon cooling, the disc snaps into the original concave form, resetting the contacts.

Remember Chace when you design for temperature actuation or indication, or for protection of valuable equipment. Dependable Chace Thermostatic Bimetal is available in 28 types, in strip, coil or completely fabricated and assembled elements made to your specification. Write for new 44-page booklet, "Successful Applications of Chace Thermostatic Bimetal", containing interesting uses of bimetal and many pages of engineering data.

W. M. CHACE CO.
Thermostatic Bimetal
1616 BEARD AVE., DETROIT 9, MICH.

New Parts

(*Continued from Page* 183)



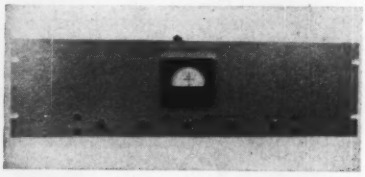
diameter from ½ to 6 in. and in length from 6 to 72 in. Studs are made from a variety of alloy steels, and have tensile strengths to 220,000 psi. **Standard Pressed Steel Co.,** Stewart Ave., Jenkintown, Pa.

Circle 716 on page 19

Voltage Check Panel

used with strain gage power supplies

Model 7102 voltage check panel is a null-type calibrator for strain-gage power supplies. It has a self-contained battery and is rated at 1.5 microamp for 5-deg deflection at null, 300 microamp continuous use without damage. Voltage adjustment is by ten-turn potentiometer and output voltage can



be adjusted to 10 v dc, ±0.02 per cent. Unit is rack-mounted on 7 x 24-in. panel. **Western Gear Corp.,** P. O. Box 182, Lynwood, Calif.

Circle 717 on page 19

Coolant Pumps

for sidewall or immersion mounting

Circulating and coolant pumps have long shaft construction which permits use at high liquid levels. Pumps are for sidewall or immersion mounting. Vent holes in supporting head protect motor should liquid level in column rise excessively. Balanced impeller is mounted directly on oversize, rigid motor shaft. Sidewall-mounted

Circle 513 on page 19

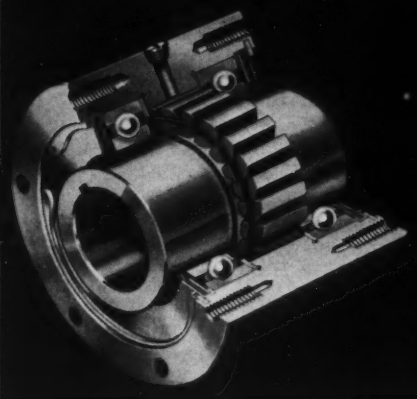
Roomful of restless men

You're looking at a roomful of design engineers. Like yourself, perhaps, they push themselves to achieve a "let's do it better for our customers" result. It's idea-creating work in a challenging mental atmosphere.

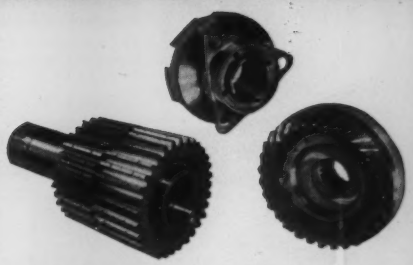
They work mostly on special clutch applications . . . been doing it for years. When a job poses a new problem they ask themselves: "Can we use one of our standard designs in this assembly rather than create a new one?" . . . More often than not their answer can be yes.

Secret of this adaptability is the result of pioneering engineering experience combined with Formsprag's basically simple design (see cutaway photo below). Imagine how these skilled designers can modify components to cover an enormous range of applications. The cost is usually only slightly above that of a standard model.

Drawing on their long experience with special application problems, Formsprag engineers are able to custom-tailor clutches from production line parts. You can rest—and plan—assured that Formsprag will design, build prototypes and volume produce special clutches to your complete satisfaction.



Standard Ball Bearing All-Purpose Formsprag Clutch. Note its simplicity of design. Between inner and outer races a full complement of sprags is inserted. Energizing springs hold sprags in contact. Formsprag construction allows more sprags to be inserted in a smaller area than other clutch designs. Result: greater torque capacity in a smaller clutch.



Special application Formsprag clutches like these can be priced advantageously when the application calls for use of Formsprag's vast fund of developmental engineering know-how. Let us send you literature that discusses in detail Formsprag clutches for standard and special applications.

Over-Running, Indexing and Backstopping Clutches for aircraft, automotive, and various industrial applications.

FORMSPRAG COMPANY

(A4-8C)

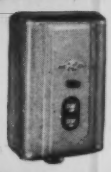
23603 HOOVER ROAD, WARREN, MICHIGAN

World's Largest Exclusive Manufacturer of Over-Running Clutches

Distributors in principal cities

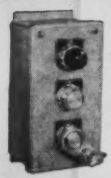
YOU SAVE 2 WAYS WITH the right control

There is a right control for every job. By using Furnas Electric controls, cost and space advantage can be yours. Designed for the motor, these controls can save you up to 25% in cost and 40% in space.



Furnas Magnetic Starters are available through Size 4 in 10, instead of the usual 5, different sizes from 1 to 100 hp. This provides "In-Between" sizes, not otherwise available, at corresponding price and space advantages.

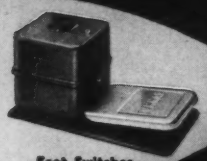
Drum Controllers—over 1000 models available from 1 to 10 hp for whatever application you require. The durability, ease of operation, versatility and low cost of drum controllers make them adaptable to the majority of applications satisfied by manual control.



Oil Tight Push Buttons for every need. Standardization and interchangeability mean more combinations with fewer parts. Complete accessory line.

Pressure Switches

Limit Switches



Foot Switches

For more information write for Bulletin 5411E, 1045 McKee Street, Batavia, Illinois

A35

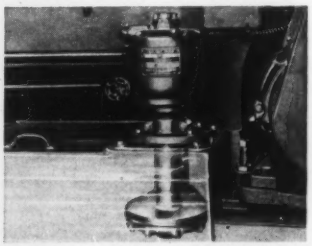
FURNAS

FURNAS ELECTRIC COMPANY

BATAVIA, ILLINOIS

SALES REPRESENTATIVES IN ALL PRINCIPAL CITIES

New Parts



units are obtainable in ¾, 1 and 1½-in. sizes with single discharge, and in ¾ and 1¼-in. dual-discharge units. Horsepower range is ¼ to 5. Immersion types are built in ¾ to 3-in. discharge sizes with horsepower range from ¼ to 10. **Ingersoll-Rand Co.**, 11 Broadway, New York 4, N. Y.

Circle 718 on page 19

Spring Material

for miniaturization applications

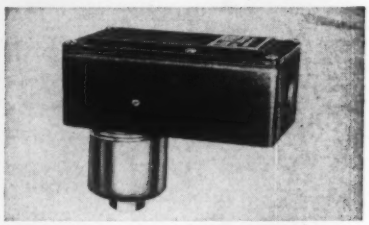
Phosphor-bronze spring material is precision-rolled to thicknesses as low as 0.0005-in., with thickness tolerances to ±0.0001-in. Use is for miniaturization applications in the electronic, electrical, automation and instrumentation industries. The material exhibits high strength, long fatigue life, good electrical conductivity, and excellent resistance to corrosion, in addition to excellent spring characteristics. It is also used in thermostat controls, bushings, shims and electronic computing tape. **American Silver Co.**, 36-07 Prince St., Flushing 54, N. Y.

Circle 719 on page 19

Pressure-Vacuum Control

for maximum pressure of 180 psi

Type J17A dual-switch pressure control provides two completely separate switch actions, permitting control of two independent circuits and flexibility of switch arrange-



Circle 515 on page 19

PACKAGED *Oil-Free* COMPRESSED AIR

PORTABLE
Compact, light in weight, insulated handle.

MOTOR
Ball bearings permanently grease packed—no re-oiling.

INTEGRATED AFTERCOOLER, PULSATION CHAMBER, MOISTURE SEPARATOR
Provides cooler, drier air at smooth, uniform pressure.

AUTOMOTIVE TYPE FAN
Assures low temperature operation for higher efficiency, longer life.

SAFETY VALVE
(Not visible)
Provides constant bleed-off at maximum pressure. Also acts as automatic moisture drain.

GRAPHITE PISTON RINGS AND SKIRTS
Special composition needs no lubrication. Self-sealing piston ring joint reduces blow-by.

DRY VALVE CONSTRUCTION
Positive-sealing without oil. Self-cleaning—no rubbing parts.

AIR WHERE YOU WANT IT... COMPLETELY OIL-FREE... COOLER... DRIER!
Expensive lubrication maintenance completely eliminated!

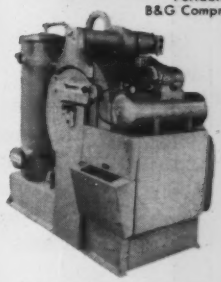
Where *clean* compressed air is essential, the B&G Oil-less Compressor provides the answer in a complete line of portable, tank-mounted and tankless models.

There is no oil required in this new design unit! Motor and compressor are permanently grease packed... graphite piston rings and skirts operate for years without destroying the mirror-finish of the cylinder walls. Since the cylinders are not lubricated, oil-free air is delivered at all times without need for an oil separator.

B&G Compressors are really *smooth!* Modern design large bore, short stroke, horizontally opposed pistons provide better balance and vibrationless operation. Compactness and light weight adapt them ideally to either portable or built-in applications. In every detail these units are designed to deliver *maximum air per horse power!*

For complete information on B&G Oil-less Compressors and Vacuum Pumps, send for Catalog GO-1156.

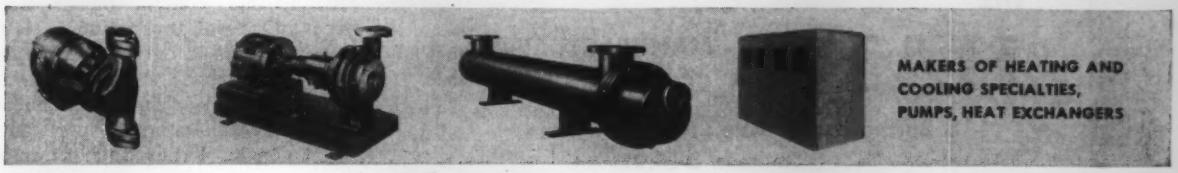
Portable B&G Compressor



B&G Oil-less Air Compressor as integral part of dry cleaning machine

Oil-less AIR COMPRESSORS

BELL & GOSSETT
COMPANY
Dept. EX-67, Morton Grove, Illinois



MAKERS OF HEATING AND COOLING SPECIALTIES, PUMPS, HEAT EXCHANGERS

Circle 516 on page 19

'DIAMOND H'

SERIES W

General Purpose Relays

MEASURE ONLY: 1½" x 1½" x 1⅞"

BUT CARRY: to 25 A. resistive at 115-230 V., A. C.; 1 h.p., 125 V., 2 h.p., 250 V., A.C.; D. C. and other higher ratings on request.

CONTACTS: DPDT, Double Break-Double Make (Form Z). Special arrangements and sequence on request.

MOUNTINGS: Socket, panel and sidewall arrangements standard; others to meet special needs.

"Diamond H" engineers are prepared to work out variations of these rugged, dependable relays to meet your specific requirements in such applications as **automation controls, appliances and air conditioning equipment,** or what you will. Just ask.

THE HART MANUFACTURING COMPANY

118 Bartholomew Ave., Hartford, Conn.
Phone Jackson 5-3491

Circle 517 on page 19

New Parts

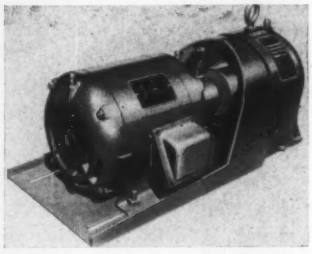
ment. Pressure settings are made individually on each switch by adjustment screws. Nine models are available in adjustable ranges between 0 and 180 psi and maximum pressures to 180 psi. Unit is available in normally open, normally closed, or double-throw types with no neutral-position models. Switches are rated for 15 amp at 115 or 230 v ac. **United Electric Controls Co.,** 79 School St., Watertown, Mass.

Circle 720 on page 19

Gearmotor

is easily replaced

Line-O-Drive gearmotor is available with capacities from 1 to 75 hp. Each reducer type has output speed range from 350 to 7½ rpm. Double and triple-reduction units have foot and flange mountings, vertical or horizontal. To change motors, four bolts are loosened to



free motor from end shelf and uncouple flexible coupling. Mounting slots in end shelf conform with NEMA dimensions. Speed-reducer ratios to 1478:1 can be changed with standardized drive components. Flexible coupling absorbs misalignment and end float through rocking action of hubs in sleeve. **Howell Electric Motors Co.,** Howell, Mich.

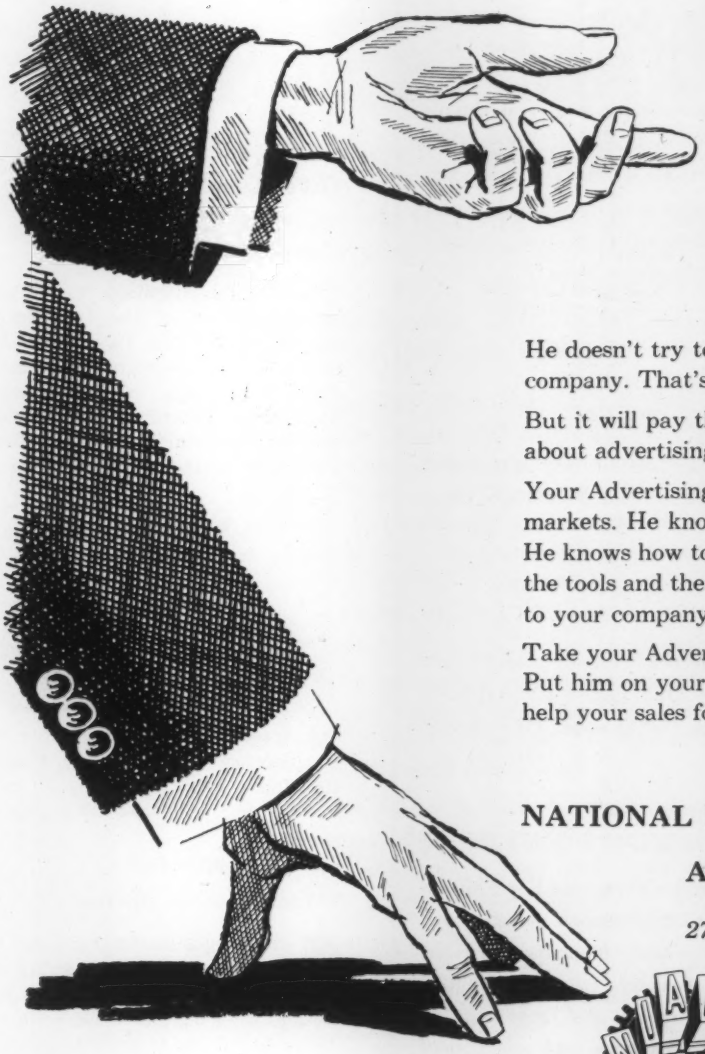
Circle 721 on page 19

Pneumatic Timing Relay

meets restricted-space requirements

Small pneumatic timing relay meets restricted space requirements of machine-tool control panels and other industrial applications. Narrow-base unit is only 2½ in. wide by 7⅝ in. high. Adjustable timing range is 0.2 second to 3 minutes with accuracy of ± 10 per cent. Ac unit can be used on circuits

Does your Board of Directors listen to this man?



He doesn't try to tell your Directors how to run the company. That's their job, and he respects it.

But it will pay them to listen to him when he talks about advertising for your company. That's his job!

Your Advertising Manager is a man who knows markets. He knows the science of "mechanized selling." He knows how to help turn sales goals into sales. He has the tools and the know-how to make major contributions to your company's progress and profit.

Take your Advertising Manager into your confidence. Put him on your first team. Let him manage. He can help your sales force sell more economically.

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271 Madison Avenue, New York 16, N. Y.

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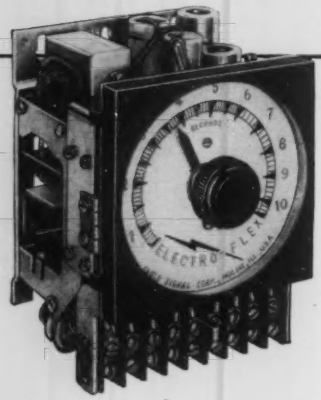
NEW *EAGLE* ELECTRONIC RESET TIMER SPANS RANGE FROM .1 TO 10 SECONDS

. . . COMPENSATED CIRCUIT MAINTAINS HIGH ACCURACY



ELECTROFLEX

Eagle's new Reset Timer employs only two moving parts (relay armatures), achieving precise short-interval timing through a dual range electronic circuit. Timing accuracy is maintained within 2% through line voltage variations from 90 to 130v. ambient temperature changes of 52°F. to 140°F., electronic tube replacements, and vibration up to 3g.

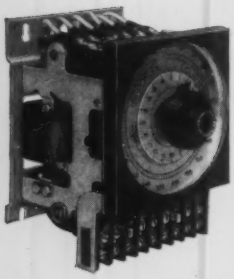
SUGGESTS NEW CONTROL IDEAS

Electroflex Dial, with precision wound potentiometer, may be mounted at the push button station with the mechanism located at a spot more convenient to wiring, installation.

PULSER

Pulsing with adjustable dwell is easily effected. Periodic output pulses may be continuously repeated with the OFF period adjustable on the dial. Pulse length (or reset time) is .050 seconds. OFF time is adjustable to 10 seconds.

COMPANION EQUIPMENT

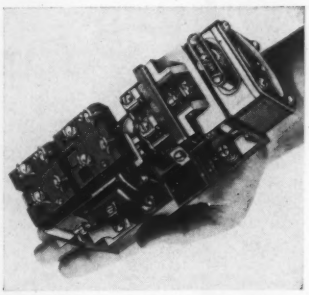


The Electroflex Timer, the Eagle Microflex Timer, synchronous motor driven for longer time intervals, and the Microflex Counter, (shown) all share the same large 4″ dial, mounting dimensions, accessories and selection of enclosures to provide uniform appearance, simplify installations.

Send for new Eagle Bulletin 150. Simply write to Eagle Signal Corporation, Industrial Timers Division, Moline, Illinois, Dept. MD-857.

Circle 519 on page 19

New Parts



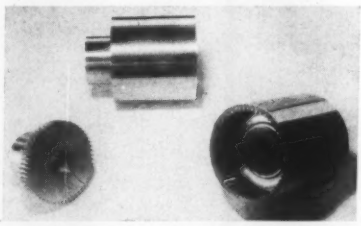
up to 600 v, and model is also available for dc service. **Square D Co.**, 4041 N. Richards St., Milwaukee 12, Wis.

Circle 722 on page 19

Clutch-Couplings

for high operating speeds

These clutch-couplings are made for connection of the two shafts by splines. They have precision roller-clutch elements and anti-friction bearings. Clutches have no springs, providing minimum of friction load during free-wheeling. They are suited for high operat-



ing speeds and high engagement frequencies. **Odin Corp.**, Castleton, Ind.

Circle 723 on page 19

Ceramic Capacitors

for transistor circuits

Six high-capacitance ceramic capacitors are used in transistor circuit applications for bypass and coupling. They have high capacitance-to-volume ratio. Capacitors are coated with vacuum-wax-impregnated phenolic insulation. Leads are No. 26 gage tinned copper wire. Sizes range from 13/64-in. sq for a 0.005 mf capacitor to 17/32 x 21/32 in. for a 0.1 mf unit. Thicknesses range from 0.090 to 0.110-in. **Mucon Corp.**, 9 St. Francis St., Newark 5, N. J.

Circle 724 on page 19

again available in reprint • • • •

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by Otto Lichtwitz

A SYSTEMATIC TREATMENT OF THE PROBLEMS INVOLVED FOR IMPARTING INTERMITTENT MOTION THROUGH EXTERNAL AND INTERNAL GENEVA AND STAR WHEELS, AND INTERMITTENT MECHANISMS FOR INTERSECTING AND CROSSING SHAFTS

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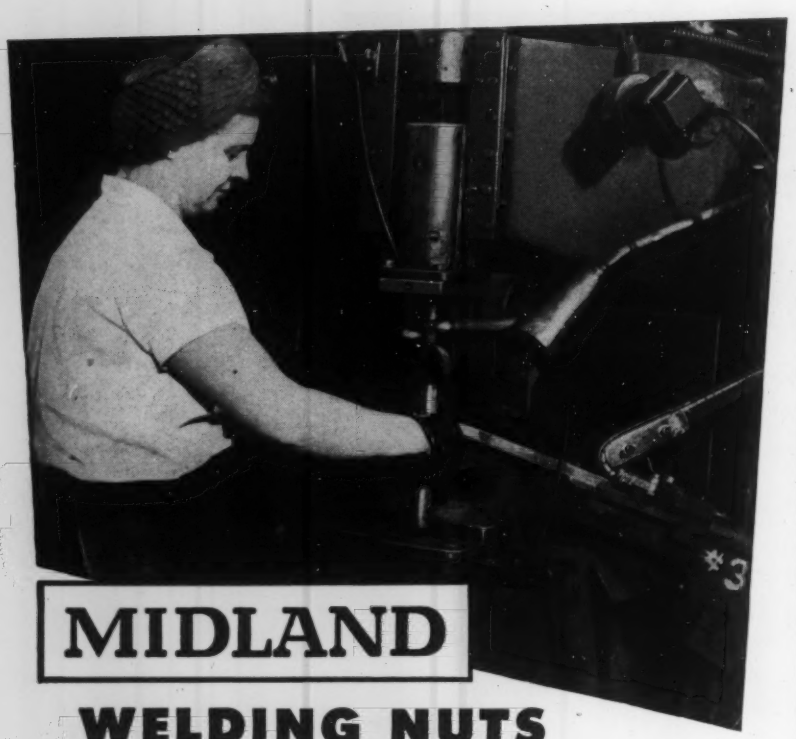

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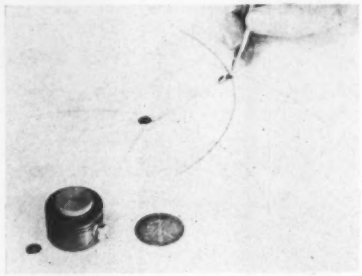
ENGINEERING DEPARTMENT

EQUIPMENT

Beam Compass

scribes circles to 12-ft diameter

Turret-shaped metal beam compass contains enough tough linen thread to scribe circles up to 12 ft in diameter, as well as large involute curves and spirals. Measurements can be controlled to a fraction of an inch by linelocking clutch and rewind knob. Pen or pencil gripsocket is clamped securely to one end of the line, and



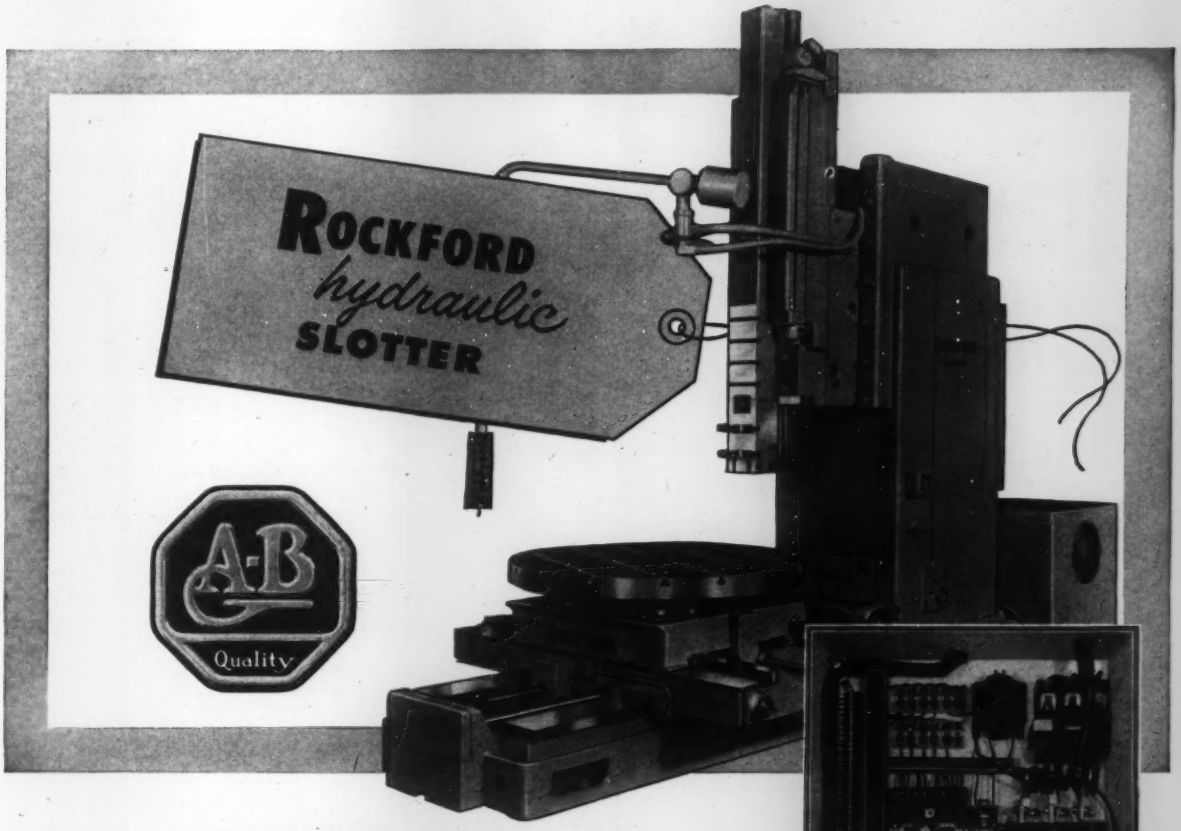
reel is anchored to work surface. Three interchangeable pins act as seating anchors, rewind handles, and curvature guides. Compass can be used with pencil, ball-pen or metal scriber. **Laramie Chemical Corp.**, 290 Main St., Stamford, Conn.

Circle 725 on page 19

Recording Oscilloscope

has self-contained bridge power

Model H-42B four-channel recording oscilloscope is used for pulse control and measurement, stress analysis, resonance, impact and vibration studies, recording radar performance, nuclear research, guided missile and other ballistics research, and similar applications. Frequency range is dc to 100 kc, ± 0.5 db, or 150 kc, ± 3 db. Four-beam tube has 5-in. flat face and provides high intensity spot for recording on moving film. Unit can be operated by

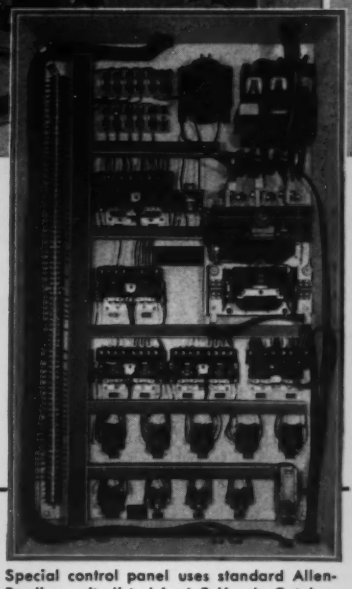


FACTORY EQUIPPED with ALLEN-BRADLEY Motor Control

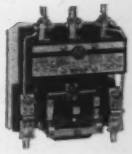
Without its "electrical brain"—the motor controls—your modern machine would hardly be a production tool. The special control panel starts, stops, and reverses its motors in proper sequence, at just the right instant. And the higher the speeds, the more necessary it is that each motor be controlled with split-second accuracy.

For modern, high speed production machines, Allen-Bradley is the *preferred* motor control. The reason for this leadership lies in the reliability and uniform operating speeds of all Allen-Bradley control units. Allen-Bradley solenoid relays, contactors, and starters have only one moving part. There are no bearings to corrode and stick. This simple design assures millions of trouble free operations. And the double break, silver alloy contacts . . . used on all Allen-Bradley controls...never need service attention.

To make sure that your machine tools are free from control failures, specify Allen-Bradley—you will never regret *this* decision!



Special control panel uses standard Allen-Bradley units listed in A-B Handy Catalog.



Bulletin 709, Size 4 Across-the-Line Starter. These starters are made in 8 sizes up to 300 hp, 220 v; 600 hp, 440-550 v.

Bulletin 800T Oiltight Control Units

Raised "STOP" Button

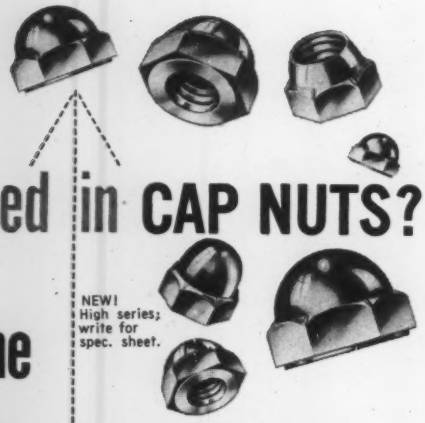
Push to Test Pilot Light

Three Position Selector Switch

ALLEN-BRADLEY
MOTOR CONTROL
QUALITY

Allen-Bradley Co., 1333 S. First St., Milwaukee 4, Wis.
In Canada: Allen-Bradley Canada Ltd., Galt, Ont.

Circle 522 on page 19



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Circle 523 on page 19

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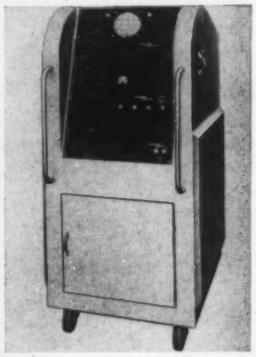
Engineering Equipment



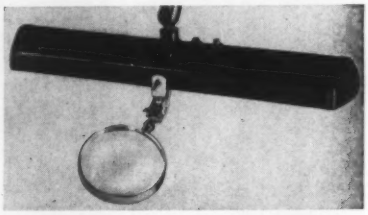
remote or direct control. It provides self-contained bridge power for all channels. **Electronic Tube Corp.,** 1200 E. Mermaid Lane, Philadelphia 18, Pa.

Circle 726 on page 19

Magnifiers

have all-position, free-swivel mount

Mounted on work or inspection benches, drafting-table lamps, machine tools, or wherever precision instruments require setting, Swivl-Clamp 4-in. diam +5 Diopter magnifiers adjust to any position with one hand. Large diameter permits use of both eyes to obtain



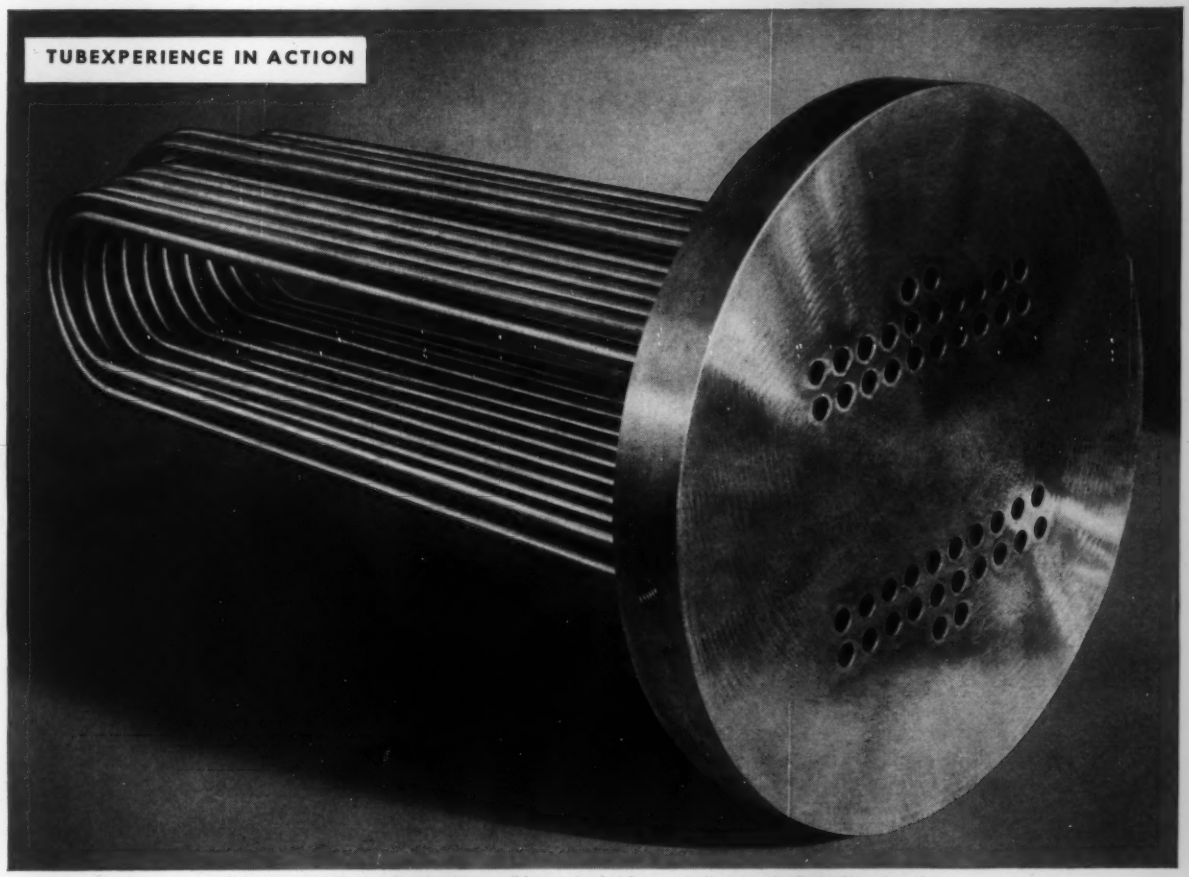
three-dimensional effect. Magnifiers have 8-in. focal length ground lens. All-metal mount is provided with free swivel. **Edmund Scientific Co.,** Barrington 21, N. J.

Circle 727 on page 19

Phasemeter

has linearity error of ± ½ deg

PM-1B phasemeter is a self-contained instrument which measures and calibrates phase relationships at audible and supersonic frequencies in complete systems and electronic instrumentation. Unit has linearity error of ± ½-deg, high-impedance input with low-impe-



Heat exchanger tubing bundle ordered by a well-known chemical firm was fabricated by the Elyria, Ohio, plant of the Pfaudler Co. Superior supplied WELDRAWN* unalloyed titanium tubing, Grade A-40, with ¾ in. OD and .065 in. wall.

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Fabricator reports: "The tubing supplied by Superior was just what we needed. And we found it would withstand a bend of 2½ in. radius without difficulty."

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Titanium is but one of over 120 different analyses available in tubing form from Superior. For complete technical information on Superior titanium tubing, get a free copy of Bulletin 44. Write Superior Tube Company, 2010 Germantown Ave., Norristown, Pa.

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All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, 5710 Smithway St., Los Angeles 22, Calif. • RAymond 3-1331

Circle 525 on page 19

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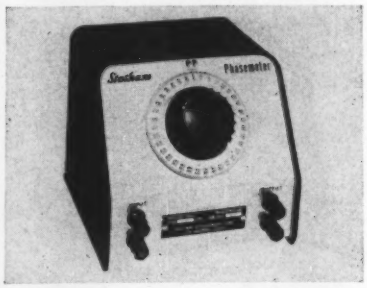
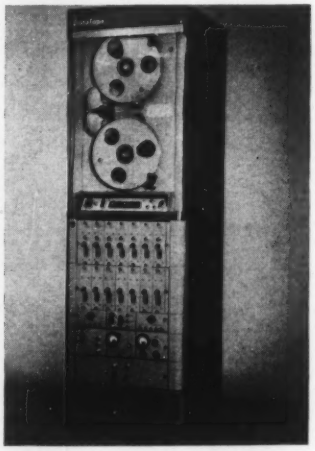


dance output, adjustable zeroing on large, direct-reading dial, and constant amplitude. It is available in two models: a single-frequency unit for any frequency between 60 cps and 20 kc; and a three-frequency unit for any three selected frequencies between 60 cps and 20 kc. **Statham Development** Corp., Dept. SP-4, 12411 W. Olympic Blvd., Los Angeles 64, Calif.

Circle 728 on page 19

Tape Recorder-Reproducer

provides fast acquisition of data



Type 5-752 magnetic-tape recorder-reproducer system handles analog, PDM, and FM signals on magnetic tape. It provides fast acquisition of large amounts of precise data. All components are located within one cabinet. Modular construction permits easy replacement of parts and interchange of plug-in amplifiers for recording and reproduction of the three types of signals. **Consolidated Electrodynamics Corp.**, 300 N. Sierra Madre Villa, Pasadena, Calif.

Circle 729 on page 19

THE ENGINEER'S

Library

Recent Books

Nuclear Engineering. *Edited by Charles F. Bonilla, Chairman, Nuclear Engineering Committee, Columbia University; 850 pages, 6 by 9 in., clothbound; published by McGraw-Hill Book Co. Inc., 330 West 42nd St., New York 36, N.Y.; available from* MACHINE DESIGN, *$12.50 postpaid.*

Written by contributors in various fields of engineering and science, this reference work gives basic principles of engineering involved in design of nuclear reactor cores and power plants. In each of 12 fields, fundamentals are given briefly with illustrations and advanced analyses valuable to the design engineer.

The book is detailed and extensive on most engineering aspects particularly in regard to fluid flow, heat transfer, stress analysis, and power cycles. Topics include mathematical analysis of plastic flow in thermal stress, design of orifices for protection of parallel coolant channels, and relative evaluation of fuel element shapes and coolants.

The Science of Engineering Materials. *Edited by J. E. Goldman; 528 pages, 6 by 9 in., clothbound; published by John Wiley & Sons Inc., 440 Fourth Ave., New York 16, N.Y.; available from* MACHINE DESIGN, *$12.00 postpaid.*

This book contains a series of lectures on Impact of Solid-State Science on Engineering Materials, based on Proceedings of the Carnegie Conference at Carnegie Institute of Technology, June, 1954.

Basic principles of solid state physics are applied to the explanation of properties of materials. Early chapters provide necessary background in modern physics and offer an analysis of the general scope and terminology of the solid state.

The book is the work of a num-

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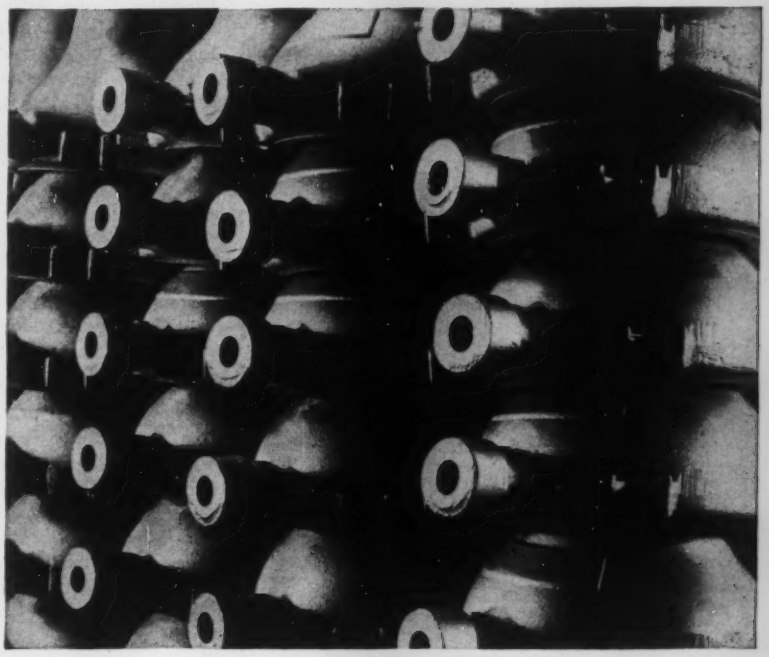

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Circle 527 on page 19

Library

ber of scientists in a variety of physical and engineering fields. Properties of metals, alloys, semiconductors, cements, polymers, and glasses are explained and interpreted qualitatively while actual molecular makeup of materials is defined.

A History of Mechanics. *By Rene Dugas, Ecole Polytechnique, Paris; translated by J. R. Maddox;* 671 *pages,* 6 *by* 9 *in., clothbound; published by The Central Book Co. Inc.,* 261 *Broadway, New York* 7, *N. Y.; available from* MACHINE DESIGN, $15.00 *postpaid.*

This book presents, in a chronological order, the evolution of principles of general mechanics from the time of Aristotle to the present day. It is divided into five parts. The first deals with the origins of mechanics and includes Hellenic science, Alexandrian sources and Arabic manuscripts, and various schools of thought up to and including the 16th century. Part two, formation of classical mechanics, presents theories and principles of Galileo, Torricelli, Roberval, Descartes, Huygens, Newton and others. Part three pertains to 18th century mechanics up to Lagrange, and part four presents characteristic features of evolution of mechanics after Lagrange. Part five contains principles of modern physical theories of mechanisms and is divided into sections on presentation of the development of quantum mechanics by early researchers. Concluding sections of part five analyze and interpret each of these theories in the light of more recent developments.

A Handbook of Hard Metals. *By W. Dawihl;* 162 *pages,* 6 *by* 9½ *in., clothbound; published by Philosophical Library Inc.,* 15 *East* 40*th St., New York* 16, *N. Y.; available from* MACHINE DESIGN, $10.00 *postpaid.*

The first part of this book deals with principles of sintering. Included are physical principles of powder metallurgy, structure and properties of hard-metal alloys, mechanical and physical properties, and tungsten-free hard metals. The second part of the book

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describes the technical production of hard metals. Detailed reference is made to experimental methods and results of other investigators.

Transistor Circuit Engineering. *Edited by Richard F. Shea, General Electric Co.; 468 pages, 6 by 9 in., clothbound; published by John Wiley & Sons Inc., 440 Fourth Ave., New York 16, N. Y.; available from* MACHINE DESIGN, *$2.00 postpaid.*

This book shows how transistor theory is put to work in typical circuits. It provides all necessary tools for actual circuit designs in potential fields of application. It also provides the know-how for building audio amplifiers, radio-frequency amplifiers, etc., using available transistors. Moreover, it shows how to combine these elements into radio receivers, television sets, and high-fidelity audio systems.

Association Publications

Technical Data on Plastics. *213 pages, 8½ by 11 in., clothbound; published by and available from Manufacturing Chemists Association Inc., 162 Eye St., N.W., Washington 6, D. C.; $2.35 per copy.*

This book is a compilation of data which present characteristic properties of commercially available plastics. Each section includes a discussion and presentation of data for plastics sharing either a certain basic composition or basic form. Tabular data were derived from tests made by individual manufacturers according to methods established by the ASTM.

The Patent, Trade-Mark, and Copyright Journal of Research and Education. *173 pages, 7 by 10 in., paperbound; published by and available from The Patent, Trade-Mark and Copyright Foundation of The George Washington University, Washington 6, D.C.; $3.50 per copy.*

This first issue of the Journal contains an introductory section on the Foundation generally, reports on completed projects, and interim reports on projects in process.

The Journal will publish scientific research regarding principles, facts, and practical operations of the patent, trademark, copyright

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Circle 528 on page 19

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and related systems of the U.S. and other countries. It will also convey information regarding the relation of the systems to industrial and social progress.

Proceedings, Standards Engineers Society, 5th Annual National Meeting, 1956. 133 *pages,* 8½ *by* 11 *in., paperbound; available from Standards Engineers Society, P.O. Box* 281, *Camden* 1, *N.J.;* $3.75 *per copy.*

This publication contains 24 papers presented at the 1956 annual meeting of the society.

Topics include decimal dimensioning, screw thread standards, automation and engineering standardization, and others, complete with photographs and figures.

Analog Computers—Their Industrial Applications. 210 *pages,* 8½ *by* 11 *in., paperbound; published by and available from Midwest Research Institute,* 425 *Volker Blvd., Kansas City* 10, *Mo.;* $5.00 *per copy.*

This publication contains proceedings of a symposium for management sponsored by MRI in April, 1956. Included are 13 technical papers and transcript of the round-table discussion.

Topics cover analog computer techniques in design and operation of engineering systems, hydraulic problems, chemical processes, economic programming, and other similar subjects.

Government Publications

Metrology of Gage Blocks, National Bureau of Standards Circular 581. 119 *pages,* 6 *by* 9 *in., clothbound; available from Superintendent of Documents, U.S. Government Printing Office, Washington* 25, *D.C.;* $1.50 *per copy.*

This book contains proceedings of a symposium on gage blocks held at NBS, August, 1955.

Topics of 15 papers included metallurgical and physical properties of gage block materials, characteristics of gage-block measuring surfaces, application of interferometry to gage blocks, and improved interferometer designs. Concluding discussions cover development of government and commercial standards and gage-block specifications.

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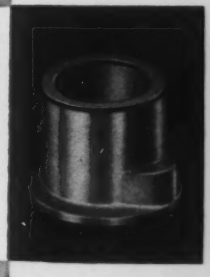

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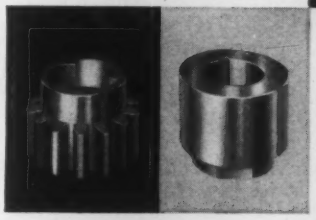

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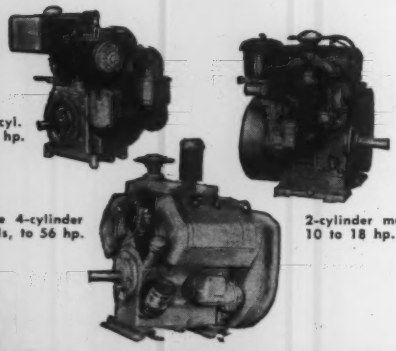

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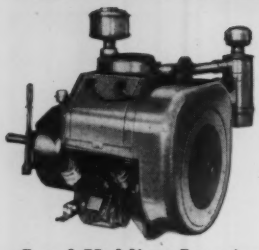

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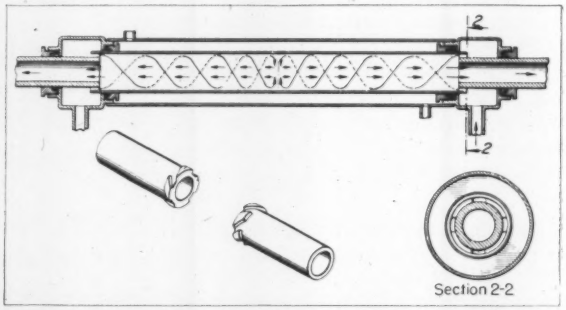
NOTEWORTHY Patents

Vortex-Tube Heat Exchanger

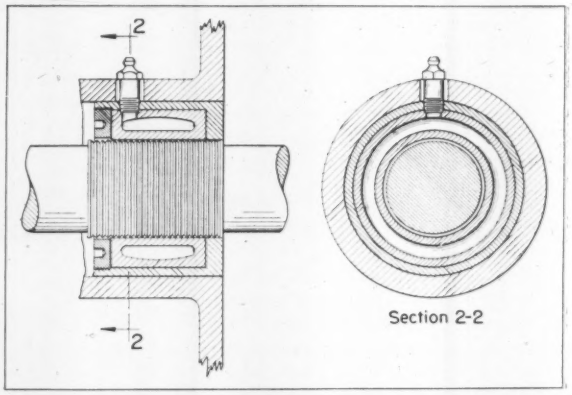
Angled inlet nozzles (lower left and Section 2-2) swirl inlet gas in a helical path to give increased cooling efficiency in an axial-flow vortex-tube heat exchanger. Flow of gas to be cooled enters at both



right-angle ported manifolds at the tube ends, then flows in a helical path along the inner surface of the vortex-tube. At approximate center of the tube, gas reverses direction and flows axially to the outlet ports. Long path followed by the swirling gas ensures high rate of heat transfer through the vortex-tube wall to the cooling medium flowing through the surrounding jacket. *Patent* 2,790,310 *assigned to Garrett Corp. by Frederick H. Green.*

Shaft Seal

Closely spaced V-shaped ridges, machined on an enlarged shaft section, wear grooves on the inside surface of a hollow Babbitt-metal sealing member to give minimum leakage in a compact shaft seal. Grease



introduced under pressure through a standard fitting initally forces the chambered sealing-member wall into tight engagement with the shaft ridges. When the shaft rotates, individual V-ridges wear into the soft-

BILL FOX, Convair's Senior Project Engineer on the F-102A, was graduated from the University of Virginia (BSME) in 1943. He has been with CONVAIR-SAN DIEGO since graduation, except for nine months with the U.S. Air Force. His success at Convair underscores the career opportunities for engineers at this "young man's company."

"Engineers—here's how the first application of 'Area Rule' made our Convair F-102A supersonic!"

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"Important as this project was, it represents only *one* of the many creative assignments being solved at CONVAIR-*SAN DIEGO*—on projects like our F-102A Interceptor and Convair's 880—world's fastest Jetliner.

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Circle 531 on page 19

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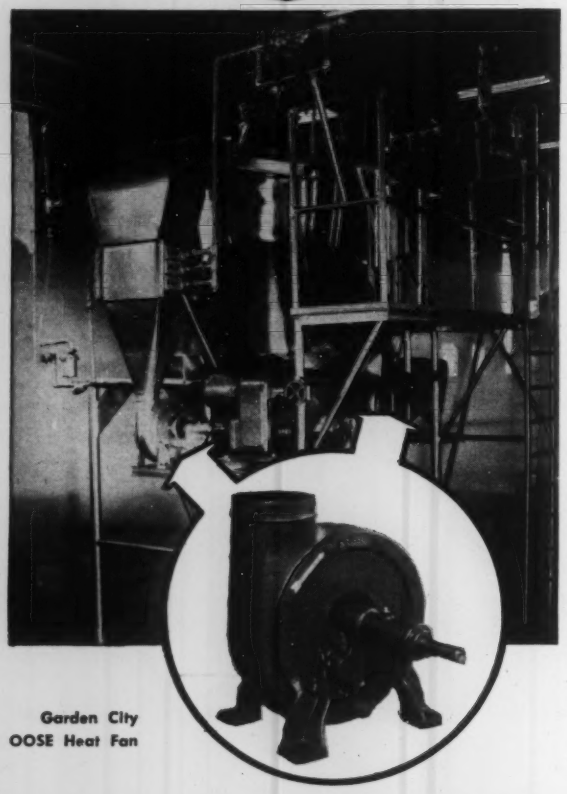

Garden City OOSE Heat Fan

Fascinating—the way this fabulous Instantizer machine converts milk into powder form! First, the water is extracted . . . then the condensed milk-liquid is exposed to a current of hot, fast moving air (created by a Garden City OOSE heat fan) which effects immediate evaporation. Then another Garden City OOSE fan whisks away the milk powder in a conveyor.

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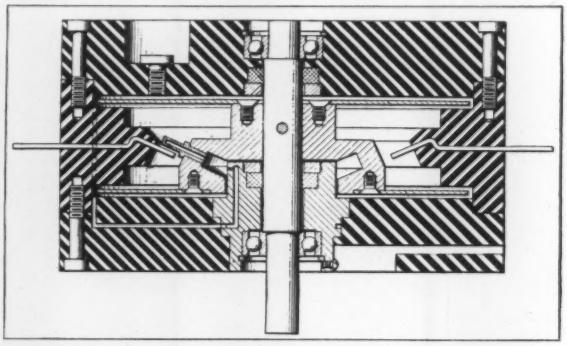
Noteworthy Patents

metal seal annulus, forming a permanent minimum-clearance tortuous path along the shaft. *Patent 2,732,232 assigned to Read Standard Corp. by Joseph E. Whitfield.*

Mercury-Jet Switch

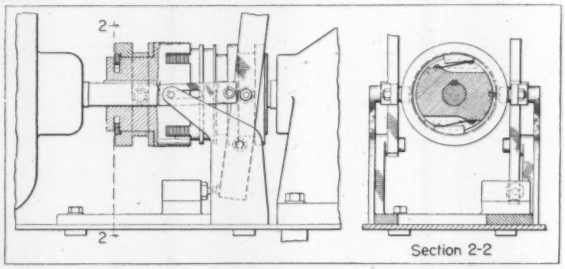
All-position mounting is possible with a high-speed rotary switch that uses a mercury jet as a "wiper arm." Ejected by centrifugal force from the



rotating jet nozzle, the mercury sequentially completes an electrical contact with multiple switch-terminal pins spaced in the switch housing. Regardless of the shaft mounting position, mercury is returned to the rotor reservoir by the centrifugal pumping action of a pair of flat-plate slinger rings. Switch action is unaffected by environmental acceleration. *Patent 2,791,650 assigned to Detroit Controls Corp. by Jerome W. Gootherts.*

Clutch-Control Assembly

Centrifugally actuated flyweights mechanically block engagement of a multiple-disk clutch when one shaft is rotating substantially faster than the other. Weights retract and permit clutch engagement when speed difference decreases to a predetermined value. Typical use is to prevent overspeed operation of low-speed-motor reduction gearing when motor is clutch-coupled in tandem with a high-speed motor. In application shown here, energized low-speed motor (right) drives load through clutch and de-energized high-speed motor shaft (left). Clutch is disengaged and low-speed motor idles during high-speed part of operating cycle. Extended position of centrifugal weights then prevents accidental engagement of clutch until speed differential between the



Circle 532 on page 19

Circle 533 on page 19→

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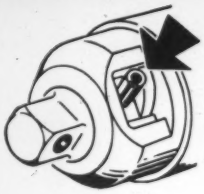
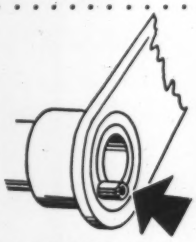
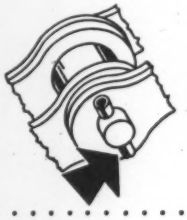


REPLACING A GROOVED PIN . . . in this application, Rollpin serves as a stop pin in a ratchet wrench adaptor. With its light weight and high shear strength, Rollpin functions perfectly . . . cuts assembly costs.



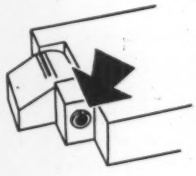
REPLACING A KEY . . . Rollpin demonstrates its ability to do away with precision tolerances, in this heating system damper arm. Faster, cheaper and more satisfactory than previous assemblies.

REPLACING A RIVET SHAFT . . . Rollpin serves as an axle for the sparkwheel of a cigarette lighter. No riveting or threading necessary . . . faster assembly. Note flush, clean fit.

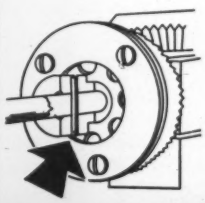


REPLACING A COTTER PIN . . . Rollpin assembly time is shorter, service life ten times longer. Vibration-proof flush fit. Easily removable.

REPLACING A SET SCREW . . . to fasten automobile brake handle a short length Rollpin is self-retained in the hand grip but can easily be driven into over-drilled hole in shaft for simple handle removal.



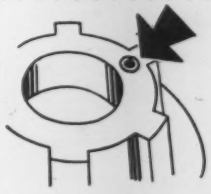
REPLACING A CLEVIS PIN . . . here Rollpin holds firmly in clevis, permits free action of moving member. Rollpin application shown is the plate of a home workshop tool.



REPLACING TAPER PINS . . . in the assembly of precision differentials eliminated cost of taper pin reamers and the entire reaming operation. Rollpin costs less than a taper pin and installation is cheaper. They remove easily.

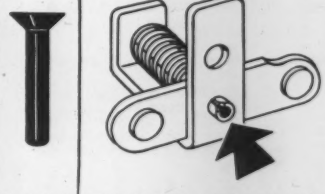
REPLACING A HEADED PIN . . . in this hinge pin application, Rollpin is simply and inexpensively driven in place, greatly reducing assembly costs. Constant spring tension holds Rollpin firmly in place . . . eliminates loosening of hinge due to wear.

REPLACING A HUB ON A GEAR . . . Rollpin, self-retained in shaft, is simply snapped into molded slot to position sintered gear. This application, by an office equipment manufacturer, effects major savings in assembly. Rollpin's high shear strength is particularly valuable here.



REPLACING A DOWEL PIN . . . Rollpin is used here to prevent rotation of a thrust bearing. No reaming, no special locking. Easily removed. Lowest possible dowel pin cost.

REPLACING A BOLT AND NUT . . . Rollpins act as fasteners and pivots for the linkages in this electric welder. Rollpins may be used with a free fit in outer or inner members depending upon product design requirements.



REPLACING A RIVET . . . Rollpin serves as guide shaft for spring-loaded electrical interlock contacts. This electrical equipment manufacturer reports that rivet failure previously occurred at the clinched end under normal operating impact and vibration.

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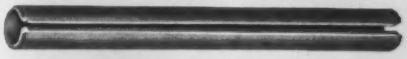

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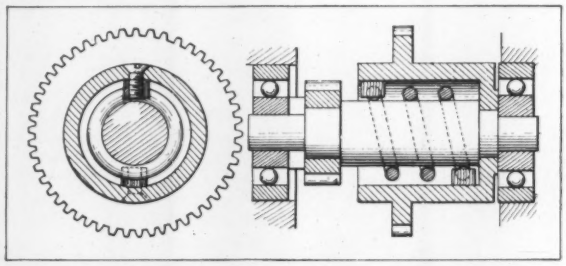
Export — Telesco International, 36 W. 44th St., New York City. Cable Code: TELESCOMM.

Noteworthy Patents

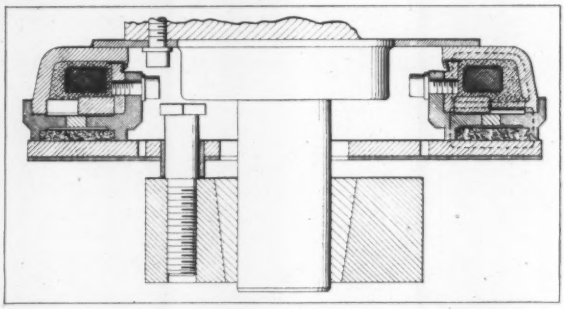
two motor shafts drops to a safe value. *Patent 2,745,997 assigned to American Laundry Machinery Co. by Leo B. Wessel.*

Slip Clutch



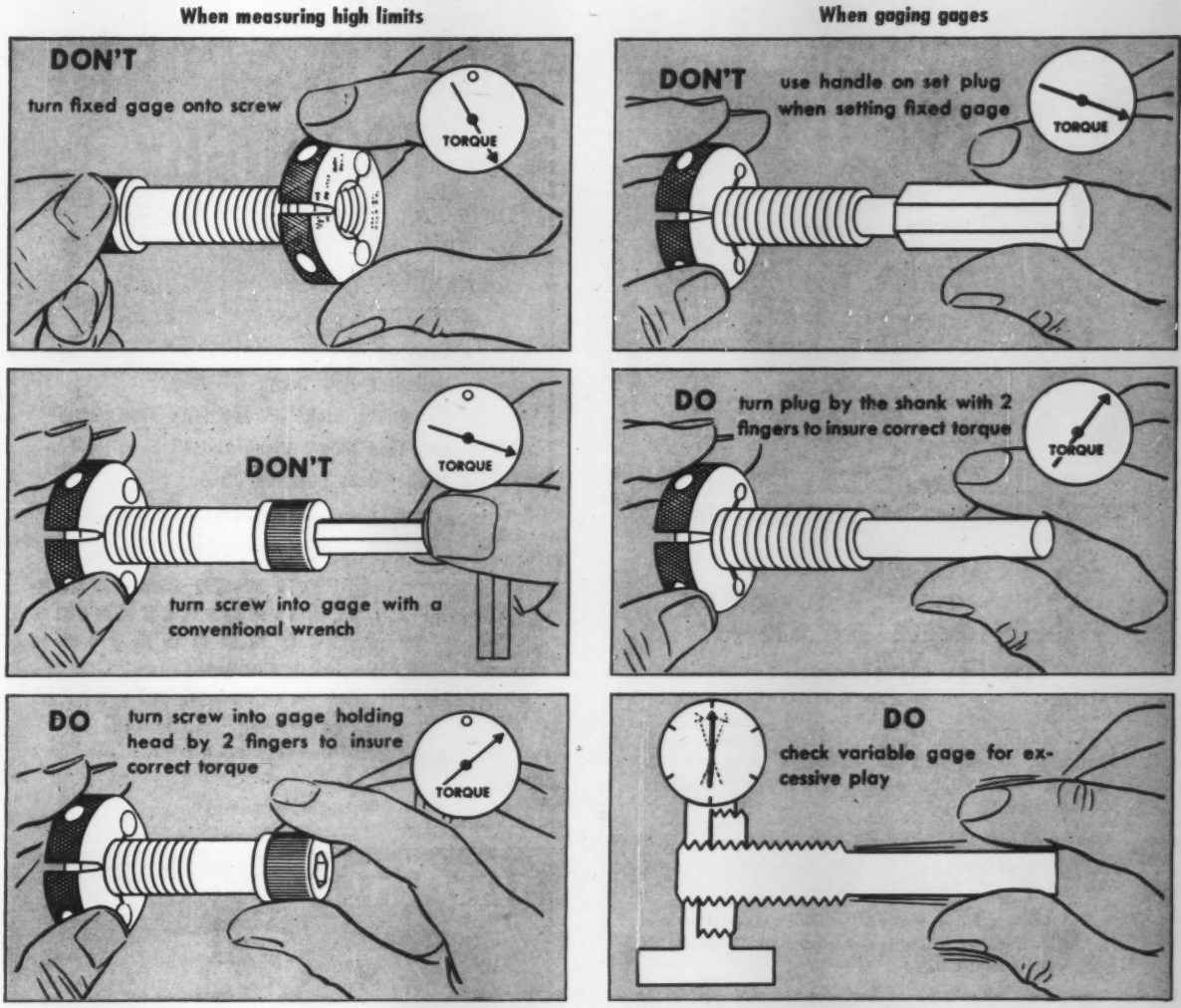
Radial clamping action of a prestressed helical spring couples input and output members of a slip-clutch assembly. Lugs projecting from the outer clutch shell engage the ends of the spring, tending to unwrap the spring from the clutch shaft as the transmitted load increases. Limit or slip torque is reached when a sufficient length of spring has been lifted from the shaft. Slip torque is independent of direction of rotation and is not affected by lubrication of the clutch surfaces. *Patent 2,793,515 assigned to Ampatco Laboratories Corp. by Francis Hunstiger.*

Magnetic Clutch or Brake



Wearing parts constitute a replaceable assembly in a permanent-magnet clutch or brake. Demagnetization of the permanent magnet during unit disassembly is avoided, since two substantially closed flux paths are provided. One is the main path extending through the U-shaped permanent-magnet annulus and friction parts; the other is a by-pass flux path which remains intact after separation of replaceable friction parts and constitutes a keeper path for the permanent magnet. Frictional engagement of the unit is derived from the permanent-magnet flux field. The magnet field is rendered ineffective and the unit disengages when an integral electrical winding is energized. *Patent 2,765,891 assigned to Warner Electric Brake & Clutch Co. by William C. Pierce.*

Copies of patents briefed in this department may be obtained for 25 cents each from The Commissioner of Patents, Washington 25, D. C.



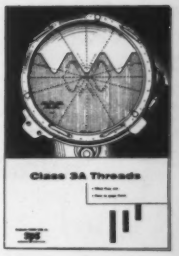
These illustrations from new SPS booklet show some of the do's and don'ts of gaging precision threads.

3A threads: what they are; how to gage them — new SPS booklet tells all

Threads made to Class 3A fit are the most precise in general use in industry. But you do not always get the 3A precision you specify. Because of many different gaging techniques that yield varying results, screws with threads well outside the Class 3A tolerance limits often pass inspection.

SPS has prepared a new booklet on this subject. It explains clearly what Class 3A threads are and the pros and cons involved in the widely varying gaging techniques in use today. It reviews the gaging of high and low limits of 3A threads, sampling techniques, and even the methods of gaging gages.

All standard UNBRAKO socket screw products fall within specified tolerance limits *no matter what method is used to gage them.* Leading industrial distributors carry complete stocks. Unbrako Socket Screw Division, STANDARD PRESSED STEEL Co., Jenkintown 18, Pa.



We also manufacture precision titanium fasteners. Write for free booklet.

Form 2239, "Class 3A Threads: what they are; how to gage them." 16 pages, with many illustrations. Write for free copy today.

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UNBRAKO SOCKET SCREW DIVISION SPS

JENKINTOWN PENNSYLVANIA

Circle 535 on page 19

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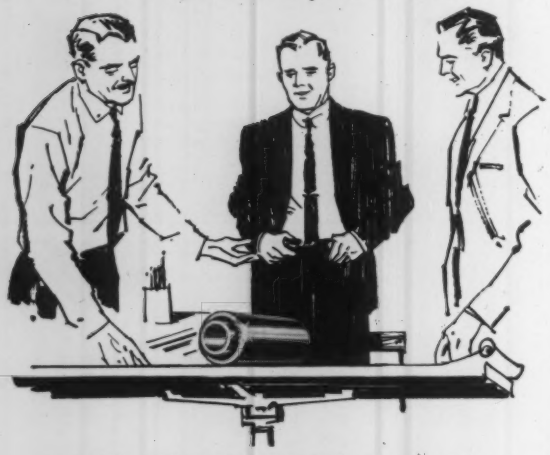

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Flexible Bearings by Bushings, Inc. absorb shock, vibration and noise. They correct for misalignment, reduce shaft-wear and help insure a quiet, smooth running, longer lasting product with higher consumer satisfaction.

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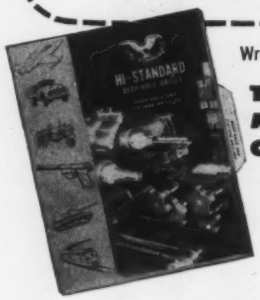

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Circle 538 on page 19

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Speed Reducers

- COMPACT
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▲ ADU UNIT RATIOS: 4 5/6 TO 100 to 1

Abart Speed Reducers are precision built to provide efficient, power conserving speed reduction and are available in a wide range of models to meet your specific requirements.

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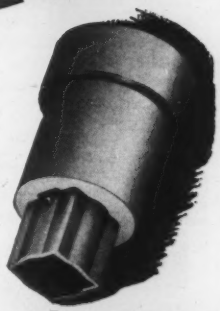
BRUSH HOLDERS



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High performance Phoenix "Pemester" Brush Holders and Caps are for motors that get the really rugged duty... new "Pemester" material gives high-impact-strength, dimensional stability up to 400°F. and molds to close tolerances in any quantity . . . Available *only* from Phoenix in the complete "Customized-Standard" line of sizes and types—or to your specifications.

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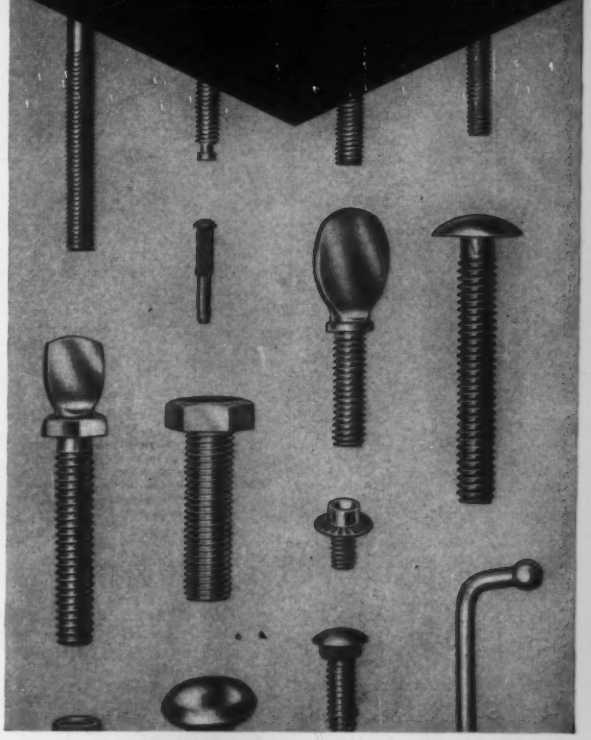
Make sure you're buying right

See **PROGRESSIVE** for parts like these



Progressive is saving its customers up to 70% on special fasteners. Very likely we can save you thousands of dollars on many of your small metal components.

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THE PROGRESSIVE MFG. CO.

Division of The Torrington Company

52 Norwood Street, Torrington, Connecticut

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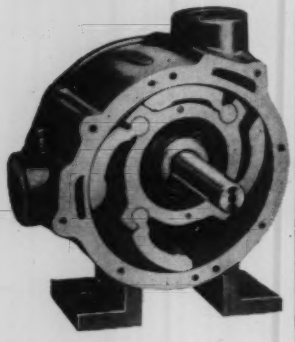
Year after year —Get steady, positive

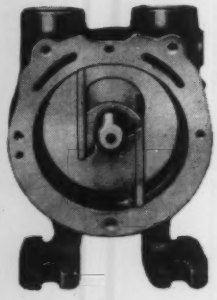
HIGH VACUUM (up to 29.9" hg.)

or

AIR PRESSURE (up to 20 psig.)



4-WING TYPE. Vacuums to 20" Hg.; pressures to 15 lbs.; displacement to 162 c.f.m. Wings hinged to pistons maintain continuous sealed contact with cylinder walls by centrifugal force. Small pistons, large air chambers, greater capacity.



2-WING TYPE. Vacuums to 29.9" Hg.; pressures to 20 lbs.; displacement to 40.8 c.f.m. Automatic wing adjusting lever forces wear-resistant steel blades to cylinder walls, preventing sticking or binding, maintaining positive vacuum or pressure.

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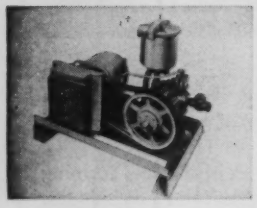
LEIMAN *Rotary* AIR PUMPS



New!
Air-cooled High Vacuum Pump
Vacuum to 29.9" hg. 15 to 40.8 c.f.m. Operates at 140°F. Write for folder.

Other types:
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- Double Cylinder Type
- Direct Connected models
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When you design a machine to operate with specific vacuum, suction or air pressure—specify Leiman Air pumps to be sure of fully-rated capacity for the life of your equipment. Forget about customer complaints, shutdowns or service calls due to air pump trouble.

Leiman Air Pumps are designed and constructed to take up their own wear—provide leakless wing-to-wall seal for years and years. Fewer moving parts—no tips or blades to renew—no maintenance except occasional oiling. Over half a million installed. Representatives and engineering assistance available in all industrial centers. Tell us your needs.

• Write for 12-page Catalog, plus Application Book showing 60 "how-to-do-it" blueprints.

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The "Lifetime" Pumps that take up their own wear
Higher vacuum–larger volume–longer life

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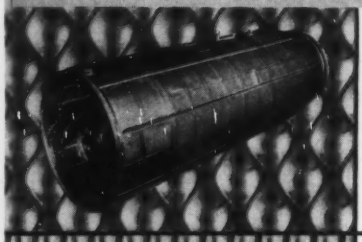
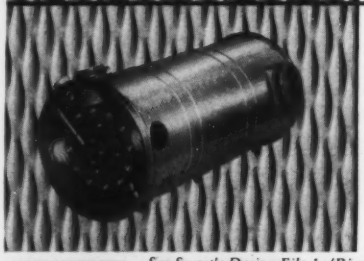
RIGID-tex METAL
demonstrates its Superiority IN THE AIR



Jet engine shroud of Titanium RIGID-tex Metal (pattern 6-WL) is 155% stronger than flat sheet fabrication yet weighs 27% less.



By eliminating rejection costs, savings of 20% were effected. Stainless RIGID-tex Metal (pattern 5-WL) made it possible. Product is an aircraft heater.

See Sweet's Design File 1a/Ri or write for more information

RIGID-tex METAL IT'S RIGIDIZED

RIGIDIZED METALS CORPORATION
6938 OHIO STREET, BUFFALO 3, N. Y.
World-wide Distribution

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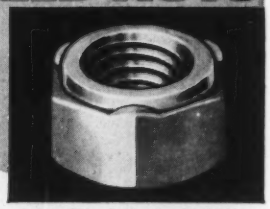
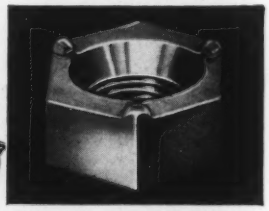
These 2 WELD NUTS
for blind assemblies



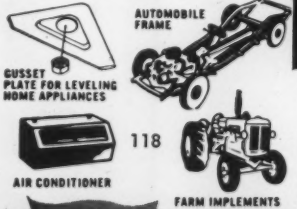
will give you
- **Easier Positioning**
- **Quicker Fastening**
- **Extra Threaded Depth at**
- **Less Cost**

Available with or without Gripco locking feature. Three weld projections on bottom of nut provide a firm non-rocking electrical connection during welding. Write for samples and full details today.

Gripco Pilot-Projection Weld Nut, circular pilot designed, provides quick, easy positioning of nut in bolt hole for instant resistant welding. No jigs, no fumbling, no waste of time. Weld spatter can not foul threads. Two heights for different metal gauges.



Gripco Countersunk Weld Nut eliminates time-wasting retapping of nuts after welding. Exclusive countersunk nut bottom eliminates fouling of threads by weld spatter. No time wasting false starts, no cleaning of damaged threads, nut ready to receive bolt immediately.



GRIP NUT COMPANY
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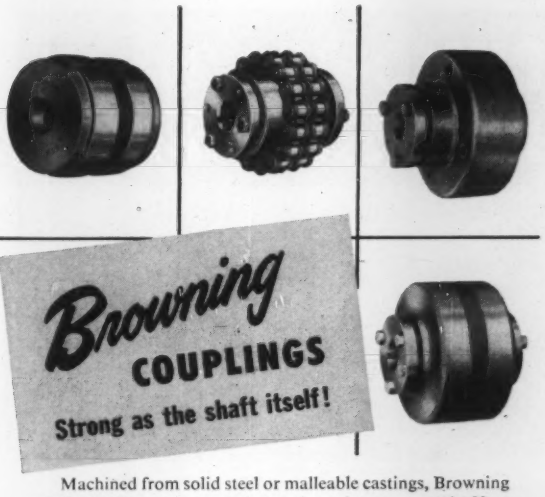

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Browning MANUFACTURING COMPANY
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Circle 545 on page 19

If GEARS Are YOUR Problem

We Can . . .

- act as your precision gear department
- keep your production line going smoothly without shut-downs
- reduce rejects, hand adjustments or other supervisory attention
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NEW design and performance opportunities when you replace ordinary bushings with HARTFORD **VERSA-TWIN*** custom bearings

When designing a new product, or improving an old one, consider the advantages in both design and performance that Hartford's *Versa-Twin* custom designed bearings offer in place of ordinary bushings of bronze, powdered metal, nylon or plastic. With *Versa-Twin* you get these advantages—

- Higher performance and longer life
- Contribute to miniaturization where desirable
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**Versa-Twin is a double-row ball bearing—made to your specific requirements—in which parts of your end product can form the inner and outer races.*

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PRECISION BALLS • BEARINGS

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AUTOPNEUMATIC CONTROL

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to thoroughly condition and control compressed air for pneumatic power tools and appliances.
- Filters • Regulates
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Assemblies and units supplied in sizes ¼"-⅜"-½"-¾"-1" and 2" NPT.

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The ARROW DRAIN TRAP
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Catalog and engineering data on request.

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NO TOOL CHARGE!

Wide selection of stock knobs, handles and plastic parts available without tooling cost to you! Many minor changes (color, design, inserts, threads, special materials, etc.) can be made to meet your requirements.

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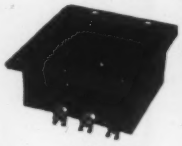
For HEAVY DUTY WORK!
Severest Electrical Services

P-506-CE—Plug with Cap



S-506-DB
Socket with deep Bracket

JONES PLUGS & SOCKETS
500 SERIES
Proven Quality!

For 5,000 Volts, 25 Amperes per Contact Alterable by circuit Characteristics.

Socket contacts of phosphor bronze, knife-switch type, cadmium plated. Plug contacts hard brass, cadmium plated. Made in 2, 4, 6, 8, 10 and 12 contacts. Plugs and sockets polarized. Long-leakage path from terminal, and terminal to ground. Caps and brackets, steel parkerized *(rust-proofed)*. Plug and socket blocks interchangeable in caps and brackets. Terminal connections most accessible. Cap insulated with canvas bakelite.

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HOWARD B. JONES DIVISION
CINCH MANUFACTURING CORPORATION
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SUBSIDIARY OF UNITED CARR FASTENER CORP.

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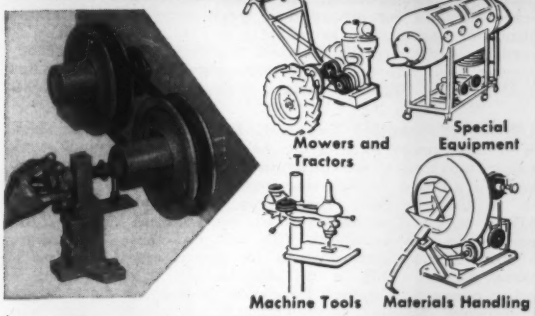
SPEED SELECTOR

VARIABLE PITCH SHEAVES

Control Speeds on Variety of Machines



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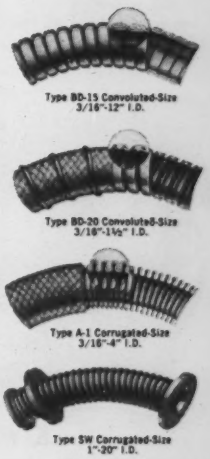
ATLANTIC METAL HOSE

Atlantic flexible metal hose is JOB TESTED & CERTIFIED to withstand the most extreme conditions of temperature, pressure and rough usage. Wall thickness is absolutely uniform. Atlantic hose cannot kink, deteriorate or burst — and requires no maintenance.

Available in steel, bronze, monel and various alloys of stainless steel with proper fittings.

Write for Bulletin No. 500A. See our Catalog in Sweet's Product Design File. Specialized engineering consultation available.

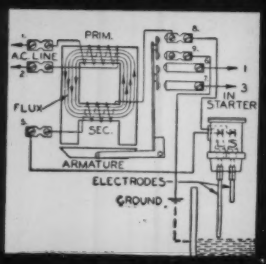

Type BD-15 Convoluted-Size 3/16"-12" I.D.
Type BD-20 Convoluted-Size 3/16"-1½" I.D.
Type A-1 Corrugated-Size 3/16"-4" I.D.
Type SW Corrugated-Size 1"-20" I.D.

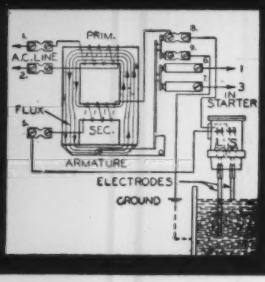
ATLANTIC METAL HOSE CO. INC.

318 Dyckman St., New York 34, N. Y.

Circle 553 on page 19

LIQUID LEVEL CONTROL
with the
B/W RELAY





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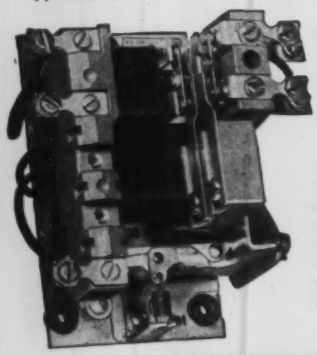

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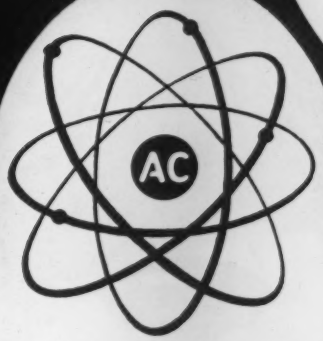

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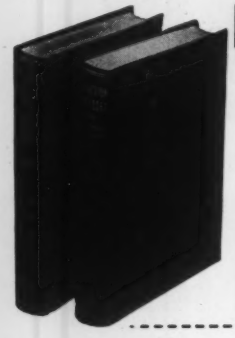

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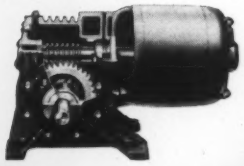

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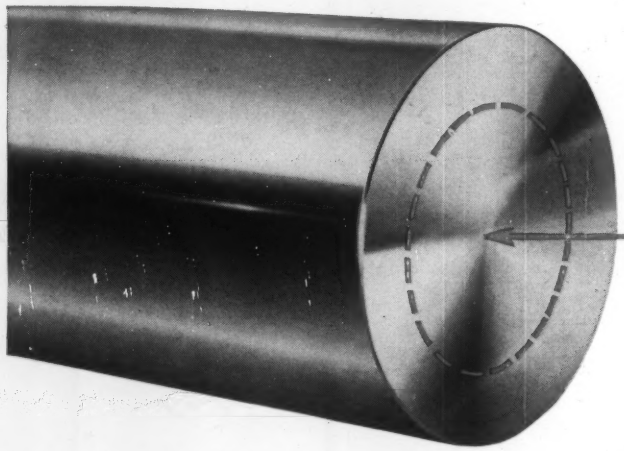

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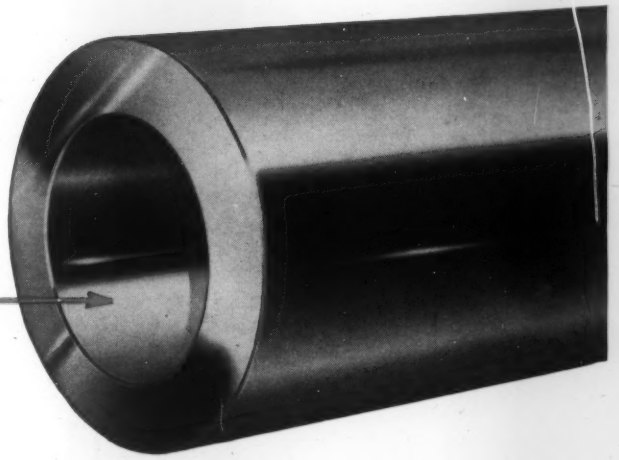

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